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transportation research program

METROPOLITAN TORONTO PLANNING BOARD 1962

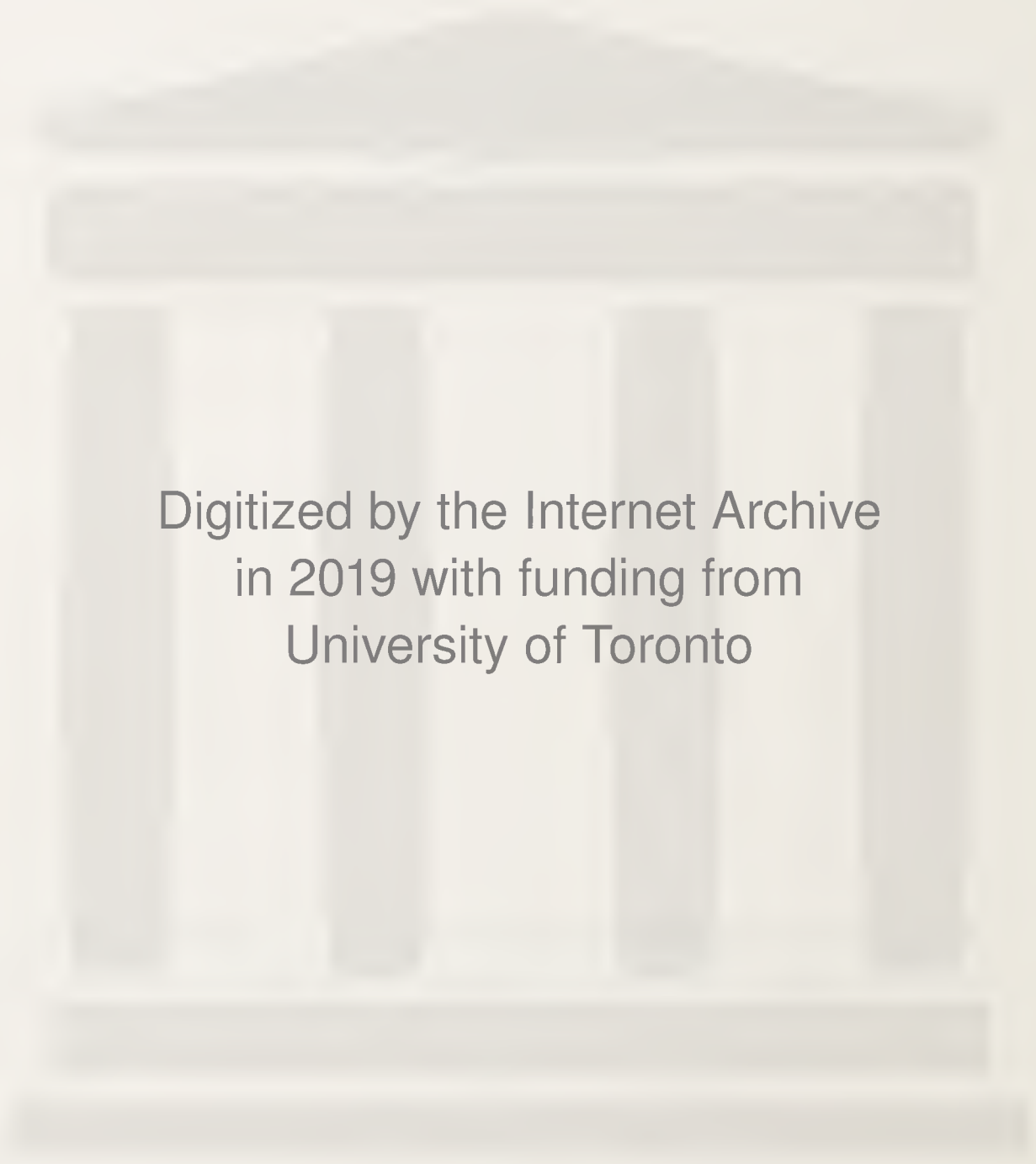
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METROPOLITAN TORONTO TRANSPORTATION RESEARCH PROGRAM

REPORT NUMBER ONE

Prepared by the Metropolitan Toronto Planning Board.
Consultants: Traffic Research Corporation (K.C.S. Ltd)

February 1962



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During the past few years considerable research has been undertaken throughout the world to devise methods of improving knowledge and understanding of transportation and its relationship to urban development. Of particular significance is the need to make decisions concerning the progressive and systematic development of a "balanced" transportation system in relation to projected land use growth.

Within the past five years the Metropolitan Toronto Planning Board has been engaged in such research studies. The "Traffic Prediction Model" developed by the Traffic Research Corporation Limited of Toronto (a subsidiary of K.C.S. Toronto) has now reached a stage of refinement where it can be used to study future traffic demand and the types and location of major facilities required to satisfy that demand.

The development of the model and the subsidiary elements necessary for its use could not have been accomplished without the participation of a number of agencies, and the co-operation of the public who participated in the factual surveys. Also, the results of research work carried out by other persons and groups added substantially to our knowledge thereby reducing the amount of our own research work that would otherwise have been necessary.

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I. INTRODUCTION

Transportation Research is Market Research

Transportation is the lifeblood of every community and provision of roads and of public transportation is one of the most important responsibilities of the Corporation of Metropolitan Toronto. Investments in transportation facilities by the Metropolitan Corporation, the T.T.C., the Province of Ontario and the railroads, are likely to total close to a billion dollars over the next 20 years.

It is evident that the most careful planning and programming is called for in making such huge investments. If we do too little too late, the development of Metropolitan Toronto may be seriously hampered. If we do too much too soon, great amounts of public money may be wasted. As in every other business, market research is required to determine the future demand for the services of each existing or proposed transportation facility. Like any other market research, this involves the prediction of probable human behaviour. Prediction is possible because, in the words of the Chicago Area Transportation Study of 1959, "travel within an urban area is extremely orderly, measurable, and basically rational".

Need for Comprehensive Transportation Research

In the past, such predictions usually have been made separately for each single facility, such as a road or a transit line. If and when an increasing number of persons and vehicles use such a facility, it is assumed as probable that this demand will continue to increase. Estimates are made, based generally on estimates of population growth, of

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the volume of persons and vehicles which will probably move in the direction of these facilities, and the volumes "assigned" to each of the parallel facilities.

Experience has shown that this piecemeal procedure is not good enough. What happens on one facility, or group of facilities, influences what happens on many others. If a new road brings more cars into a certain area they will use more road and parking space in the area. If a new facility makes shopping centre 'A' more accessible to the residents of area 'X', fewer residents of that area will travel to shopping centres 'B' and 'C'. If replacement of a streetcar line by a subway cuts travel time in half, more people will decide to use transit and fewer will drive on parallel roads; and so on. It has therefore long been recognized that realistic assignments can only be made by dealing with a transportation system as a whole. In fact, we are dealing with three interacting systems: the road system, the transit system, and the railroad system. Comprehensive transportation research must deal with these three systems as part of a total transportation system.

Traffic Generation

Such a comprehensive approach must go back to the origins of travel and find out why people travel, when, where, by what means, and by what route. The first step is to find out how many trips will be made from and to each area or "zone". This depends on the number and characteristics of persons living in each zone, the number of places of work, and the number of opportunities for shopping, recreation, etc. to be found in each zone, all of which are both origins and destinations of trips. The total number of trip origins or destinations - which are, of course, identical - found in each zone, is called the "traffic generation" of that zone.

Trip Distribution; the "gravitation formula"

Traffic generation gives the number of trips which have their origin (or destination) in a given zone but it does not say where they will go. Experience shows that the number of trips between two zones is proportional to the opportunities (for residence, work, shopping etc.) in each of two zones and inversely proportional to the square (or some other power) of the distance - in terms of time and of cost - between the two zones; modified by competing opportunities in all other zones. These relations have been first systematically investigated in research of the market for shopping centres. The formulas, expressing these relations, have been called gravitation formulas because of their similarity to Newton's classical formula.

The gravitation formula is the basic tool for determining the distribution of all trips between all zones. In the present case formulas have been developed for four different trip purposes: home; work; shopping and business; and social-recreational.

Travel Mode and Travel Route

Gravitation formulas give the number of trips made from each zone to each other zone; but they do not say by which "mode" of travel and by which route these trips will be made. Experience shows that the choice of mode and of route depends on a number of factors, of which relative time and cost are the most important. Systematic observations of the relation of these factors to choice of route were first made and analyzed by highway engineers in comparing the travel volumes on expressways with those of competing roads. The results have been expressed in the form of "indifference curves" which indicate the degree of attractiveness of one route over other available routes.

On the basis of systematic analysis of a great number of observations in the Metropolitan Toronto area comparable indifference curves have now been developed to describe the choices between driving and using transit. By the use of these methods each trip is assigned to a given route, either on the road system or on the system of public transportation.

Dependent and Independent Variables

In this way the behaviour of all persons making trips is "simulated". The simulation is derived from the observed and measured influence of certain factors on human behaviour. The influencing factors - number and characteristics of persons, number of work places, car ownership, road capacity, travel time, transit fares, etc. - are called "independent" variables. The choices made under the influence of these factors, choice of purpose, destination, mode and route of each trip made by each individual are called "dependent" variables. The correlation between dependent and independent variables is found by a statistical method known as "regression analysis" and is expressed in a number of mathematical equations. These equations are "tested" by applying them to a set of independent variables observed at a given point in time in the past and comparing the dependent variables produced by the equations with the dependent variables actually observed at the same point in time. The independent variables used in this research program were for conditions existing in Metropolitan Toronto in 1956.

Probability Theory

At first sight it may seem unrealistic to try to predict or "simulate" human behaviour. All of us frequently act irrationally, dependent on mood or impulse. The saving grace

lies in the law of averages. Individual deviations from the course of action predicted on the basis of the independent variables tend to cancel each other out. Thus, while individual events are not predictable, masses of events distribute themselves in a predictable way. The theory of probability deals with these distributions; it is widely used in business as well as in science. An example are the life expectancy tables used by insurance companies. It is obviously quite impossible to predict when Mister X, aged 55, will die. But it is perfectly possible to predict what percentage of 100,000 Canadian men, aged 55, will die within 5, 10 or 20 years.

Before the development of life expectancy tables, the business of insurance companies was also based on assessing probability, but the assessment was based on hunches and was sometimes wide off the mark. Similarly, traffic planning has always been based on the probability that somebody would use the proposed roads. The "model" which has now been developed in order to "simulate" traffic behaviour replaces estimates of the probability of human behaviour by hunch by a scientific assessment of probability.

Use of an Electronic Computer Program

Because of the great number of calculations which have to be made in order to assess the relation of a number of independent variables on a number of dependent variables for potential trips from each zone to each of the other zones, it would be quite impossible to carry out this kind of study by human labour. Fortunately the development of electronic computers makes it possible to perform this work in a fraction of the time required by the human brain.

This does not mean that human brains are no longer

required. The machine can tabulate, calculate, and store information. The formulation - or "programming" - of the questions submitted to the machine as well as the analysis of its answers still requires human judgment. The results of the machine process are not infallible truths. There are two possible sources of error.

First, the independent variables, which are "fed" into the machine, such as data on future distribution of population and employment, are estimates. If actual development should lead to a different distribution, traffic behaviour would also be different. However, if and when development should indicate the need to revise the estimates for the independent variables, the computer program is set up to deal with such revised estimates and to revise the resulting traffic assignments.

Second, human behaviour in the mass could change over time. In this case the equations which express the relations between dependent and independent variables would no longer be valid. However, in this case also, the computer program is able to derive revised equations from observations of changed behaviour.

The possibility of error is not excluded but it is greatly reduced; and, more importantly, errors can be detected and corrected much more rapidly and reliably than would otherwise be possible. The Traffic Prediction Model which has been developed in the course of the past two years, represents a very complicated, highly flexible tool for the prediction of traffic behaviour under any conceivable alternative set of conditions.

The following pages describe the process by which this tool has been developed and the ways in which it can be used. More detailed technical descriptions are also available.

II. GENERAL DESCRIPTION OF THE TRAFFIC PREDICTION MODEL

In the total operation three major phases are to be distinguished.

- 1) Basic Input Data
- 2) Computer Programs
- 3) Output Data Analysis

1) Basic Input Data

Input data comprise three different groups,

a) Transportation Facilities Grid Data, b) Land Use Data and, c) Equations Expressing Travel Characteristics.

a. Transportation Facilities Grid Data

The road, transit and rail commuter facilities are represented in the model by a system of 'links' and 'nodes'. A link is the travel path between two adjacent nodes and a node is the point at which links intersect. (see Plate 3)

One link can represent any number of closely parallel roads provided the corresponding traffic value of the link is described. All links are directional so that a bi-directional travel path between two nodes A and B would be represented by two links A to B and B to A. Link data required to describe the essential characteristics of each transportation system are:

Road system:	Number of traffic lanes
	Node to node length
	Capacity function
	Use by transit
Public transit system:	Transit vehicles per hour
	Node to node length
	Operating speed of rapid transit

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Rail commuter:	Number of trains per hour
	Length between stations
	Operating speed
	Fare structure

Nodes have two functions:

1. to locate and identify significant points on the road, public transit and rail commuter transportation systems as designated by links.
2. to identify data zones and their location in relation to the network of transportation facilities.

At the present time only 600 nodes in total can be used to describe the network of transportation facilities and the data zones. To conserve nodes and thereby permit a reasonably detailed description of the transportation network many nodes perform a dual or treble function. Thus, one node can be used to identify an intersection, represent a data zone and also a rapid transit or rail commuter station.

For technical reasons a node signifying an expressway interchange is not generally used also to represent a data zone.

b. Land Use Data

The type and density of land use development and human activity of an area are recorded in data areas such as census tracts, enumeration areas and other specially defined land areas. The size of these data areas vary from a few city blocks in the high density areas to sparsely developed concession blocks on the fringes of the study area.

Data recorded in each of these data areas are obtained either from specific studies undertaken by the staff of the Metropolitan Toronto Planning Board or from other

public and private agencies. These land use data used by the Traffic Prediction Model are:

- Total population
- Population under 4 years of age
- Number of dwelling units
- Residential acreage
- Developed zone acres
- Total zone acres
- Number of cars
- Total employment opportunities
- Wholesale and manufacturing employment opportunities
- Retail employment opportunities
- Parking cost and parking capacity
- Average income index
- Spacing of transit stops
- Transit trackage in tenths of a mile

For use in the model these data areas are grouped together to form zones. Thus the total study area is subdivided into not more than the present limitation of 500 data zones. Land use information originally recorded by data areas is combined accordingly into the appropriate data zones.

For the purpose of identifying the zones and their location in the transportation network each zone is represented by a numbered zone node. This is mostly a road intersection node that falls within the area of the zone. All trips subsequently calculated to move into and out of the zone are then assumed to move to and from the zone node.

Plate 4 shows the zones and corresponding zone nodes used for the 1956 test study of the Traffic Prediction Model.

c. Equations Expressing Travel Characteristics Analysis of survey data

To develop a model capable of predicting traffic flows it is necessary to determine the significance of the

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factors that motivate person trips and influence their travel characteristics. In order to do this studies are carried out to determine:

1. the relation of person and vehicle traffic movement to land use patterns.
2. the relation of traffic movement to transportation systems.

These relationships are expressed mathematically in the Traffic Prediction Model which incorporates various techniques to simulate the overall pattern of movement at any given time and in response to given input data of fundamental importance to the entire process. Of the three elements required to study these relationships the type, extent and distribution of land uses and the type, extent and characteristics of the available transportation system were obtained from factual studies. Data concerning person and vehicle movements representative of average weekday traffic were secured by a number of surveys conducted within Metropolitan Toronto. Wherever possible all data were secured to represent conditions pertaining to the year 1956.

Worker Survey (1954) established the origin to destination movements of workers and their mode of travel.

Public Transit Surveys (1955 and 1956) established the O-D movements of transit passengers by time of travel, route of travel, purpose of trip, and points of transfer.

Home Interview Survey (1956) established the trip generation of households in relation to household characteristics such as number of persons in household, occupation, car ownership, number of trips made for each purpose and their mode of travel.

External O-D Survey (1956) established the O-D movements of vehicles and passengers classified by trip purpose as entering Metropolitan Toronto on roads only.

Basic travel decisions

The critical component of the Traffic Prediction Model is the development of mathematical equations that express and are therefore able to predict person travel characteristics. These equations must simulate, with reasonable accuracy, why, where, when, how and by what route people will travel under any set of conditions likely to influence these travel decisions. These five travel decisions common to all trips are:

- i) Why: purpose of the trip
- ii) Where: destination of the trip
- iii) When: time of the day trip is made
- iv) How: mode of travel used (auto, transit, rail)
- v) Route: route of travel

These travel decisions are highly interrelated: thus, a trip for a particular purpose is readily identified with a trip destination and time of day; these decisions usually dictate the choice of travel mode which then influences the choice of route of travel.

Subsidiary travel considerations

The decision making process in each of these five basic travel characteristics involves consideration of any number of subsidiary factors.

i) Purpose of the trip

Why a trip is made is readily answered by the need to work, shop, etc. The trip purpose is therefore the decision that most influences all subsequent travel decisions. A secondary influence of trip purpose is whether it constitutes

a habitual trip such as to and from work and school. Since habitual trips tend to establish consistent origin-destination patterns, for the same time of day and by the same mode and route of travel they can be expressed mathematically with the least difficulty and with the most accuracy. These trips comprise about 75% of the morning peak hour traffic.

Non-habitual trips are more difficult to express mathematically because of their apparent random behaviour. During a peak hour however these trips are influenced by any number of subsidiary decisions. The peak hour itself and the time of day at which they occur probably has the greatest significance on these non-habitual trips. Because they comprise such a small percentage of both peak hours the larger error in their predictability does not significantly effect the overall accuracy of the results.

ii) Destination of the trip

Since a trip for a stated purpose is made only to a place where that purpose can be satisfied it can be concluded that trip destinations and trip purposes are complementary. Thus, for a given trip purpose the trip destination is influenced by the availability of the corresponding land use in relation to the place of trip origin. In the Traffic Prediction Model these trip destination purposes are represented in each zone by the type and extent of the various land uses and their trip generation and attraction qualities.

The significance of travel time in making travel decisions is also evident in the choice of the trip destination for a given purpose. Thus, there is a significant relationship between trip purpose and the time people are willing to spend travelling for that purpose.

Studies in many cities have shown that for a given trip purpose the most significant factors influencing choice of trip destination are: the total number of trips to be distributed from the trip origin in question, the type and extent of attractions offered by possible zones of destination and the travel time required between the origin and these destinations.

iii) Time of the day trip is made

On an average working day the heaviest traffic demand occurs during the morning and evening peak hours. This is created by the extreme ebb and flow of persons moving between home and place of employment. For traffic prediction purposes the peak hour time periods of the day are significant for two reasons; they provide a measure of the peak traffic demand and they contain a large proportion of work trips for which the travel decisions are highly predictable.

iv) Mode of travel used

A decision in the choice of travel mode involves consideration of a great many factors although the individual may only scan a few of these as being directly applicable. For example, the choice is readily made for those persons not owning a car or those to whom public transit service is not available.

To develop reasonably reliable methods which predict the choice that travellers are likely to make between these alternate 'modes' was the most difficult part of the work. The choice depends on many factors, relative travel time and cost, availability and cost of parking, time for walking to and from stations or stops and for waiting for buses and trains, as well as on such characteristics of the travellers

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as income and car ownership. All equations used in the model to express choice of travel mode have been derived from a careful analysis of a great volume of traffic and transit data assembled in the Metropolitan Toronto Area.

v) Route of travel

A person making a trip by either motor vehicle or transit usually has a choice of several travel routes between the origin and destination of the trip. Experience shows that, for a chosen travel mode, the route providing the shortest travel time will be that most frequently used; routes requiring longer travel times will be used less frequently, in proportion to the difference in travel time.

2) Computer Programs

General Role of Computer Programs

Because of the complexity and mass of mathematical calculations required to translate the derived formulas and input data into actual person trips and traffic flows, it is necessary that a high speed, large capacity electronic computer be used. These mathematical equations therefore have to be transcribed into computer language and computer programs have to be developed to simulate actual traffic conditions as closely as possible.

The computer operation therefore uses mathematical equations to predict the decisions that persons will make under the stated conditions and the resultant distribution of traffic to the transportation facilities.

Computer programs developed for the model are in three groups; Auxiliary Input Programs, Main Programs and Output Analysis Programs.

Before the main program can be put into operation, auxiliary programs have to prepare the input data in a form suitable for further use. The most important of these auxiliary input programs is the Trip Generation Program.

Trip Generation Program

The trip generation program calculates the number of person trips by trip purpose leaving and entering each zone during the stated time period of an average working day. These person trips fall into two categories, Primary trips and Secondary trips.

Primary trips have either their trip origin or trip destination at the place of residence; for example, from home to work, home to school and vice versa. Specific zone input data and trip generation equations are used to calculate the number of primary trips that will originate in each zone and will in turn be attracted by each zone.

Secondary trips have neither trip origin nor trip destination at place of residence; for example, from work to shopping or from shopping to recreation. Thus, specific trip generation formulas are used to calculate these secondary trips originating and attracted to each zone.

Main Program

The main program is the functional portion of the Traffic Prediction Model. It is comprised of six program blocks which are repeated in order any number of times as required to reach a cut-off point referred to as the settlement of traffic on the given facilities. Each repetitive cycle of the main program blocks is referred to as an "iteration". The five basic travel decisions common to all trips are simulated by these program blocks, the interaction of which also

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simulates traffic movement on the given transportation facilities. These programs which interact as a group comprise:

1. Route Generation Block
2. Travel Factors Block
3. Trip O-D Interchange Block
4. Mode and Route Proportional Split Block
5. Route Assignment Block
6. Travel Time Block

The function of each of these program blocks is briefly described.

1. Route Generation Block

The route generation block makes use of travel time in performing its two functions:

- a) It constructs, for all travel modes, up to nine shortest travel time routes between each pair of origin and destination zones.

- b) Route travel times between each O-D pair are reviewed at each iteration of Block 6 which uses for this purpose the traffic volumes assigned to each route link by Block 5.

- a. Construction of travel routes

- Types of routes

Transportation facilities link data are used by the route generation block to construct up to nine different travel routes between each zone and every other zone. These routes are divided as required between four different types of route.

- i) Motor vehicle (V) routes (excluding transit)

These routes are for automobiles and trucks. Routes between each O-D pair are constructed both with and without the use of expressway links.

ii) Transit (Q) routes

These routes are for transit service and include buses, streetcars, rapid transit and rail commuter trains. Public transit routes between each O-D pair are constructed both with and without the use of rapid transit links.

iii) Mixed routes (VQ and QV)

These routes are a combination of motor vehicles and transit routes. They enable a trip to be made using both travel modes in any order. Thus, an automobile can be driven to a commuter station from which point the remainder of the trip is made via transit. Since this traffic prediction model has been designed to deal mainly with rush hour conditions, there are two versions of the model. In the a.m. program VQ routes are generated and in the p.m. program QV routes are generated.

iv) Truck routes (T)

These routes are constructed by a special run of the route generation block. This is required only where some links in the road system are not available for use by heavy trucks during the time period under study.

Construction of routes

Travel routes for each mode are constructed between each O-D pair by stringing together any number of connecting links. By a rapid process of trial and error all links emanating from an origin node are scanned to determine those permitting the best travel times. While the slow links are discarded, the remaining links are extended in all directions by the best adjoining travel links. As the various possible routes converge on the destination node, the slower routes are continually discarded until finally only that route providing the fastest travel time is retained.

Although nine sets of routes can be constructed to represent all traffic facilities, only one route for each mode is constructed during each iteration of the route generation block. Several iterations are required therefore before all of the routes are available.

Link travel times

To provide link times for the initial set of routes constructed by the iterations of the route generation block all links are assumed to operate at their legal speed limits or reasonable operating speeds. Transit routes coinciding with motor vehicle links are constructed by using operating speeds corresponding to the speed of motor vehicles on that road section. Rapid transit and rail commuter lines using separate rights-of-way are assumed to have a constant operating speed precalculated on the basis of station spacing, equipment and riding comfort.

Given the assigned volume of cars per hour and the vehicle capacity per hour of a link it is possible to calculate the travel time required to traverse the link. This travel time information for all road links is calculated by each iteration of Block 6 and used by the subsequent iteration of the route generation block.

Because link travel times are taken into consideration when new routes are constructed these new routes tend to avoid areas which are shown to be congested. The effect of this procedure is to allow travellers a choice of diverse routes between all O-D pairs. This is illustrated in Plate 1 where routes are shown that have actually been constructed in connection with the 1956 test study.

b. Revision of route travel times

The second function of the route generation block is to revise the route travel times that have been calculated and used by previous iterations of the main program.

Since these routes were constructed under different conditions of link travel times, it is necessary to trace each previously generated route, substitute current link travel times for old ones and then determine the current route travel time pertaining to each O-D route.

The link travel times used by this block are calculated at each iteration of Block 6 based on the link data and traffic volumes loaded onto each link by the assignment program Block 5.

2. Travel Factors Block

Travel time is a significant element in three of the five basic travel decisions, namely: choice of trip destination, choice of travel mode and choice of travel route. Using the average O-D travel time calculated in Block 1, factors are developed to express the effect of travel time for each O-D trip in each of these travel decisions.

a. Trip O-D interchange factors derived for each O-D movement indicate the proportion of total trips emanating from a zone that will be made to each destination zone. These factors are then used in the 'gravity formula' of Block 3 to calculate the actual number of trips to be made between each O-D pair.

b. Travel mode factors indicate the proportion of the total trips between each O-D pair that will be made by automobile and transit. These factors are then used in Block 4 to calculate the actual number of trips by each mode.

c. Route choice factors indicate the proportion of total trips between each O-D pair and for each travel mode that will use each of the travel routes previously constructed by the route generation Block 1. These factors are then used in Block 4 to calculate the actual number of persons that will travel on each route.

For each cycle of the main program blocks the travel times between each O-D pair vary in accordance with the simulated traffic loading on links of the transportation system. Because travel time has a considerable influence on each of these three travel decisions it is then necessary that they be able to revise decisions made in relation to the travel conditions existing during previous cycles of the program. This is made possible by revising these travel factors in accordance with the changes in travel times calculated in Block 6.

3. Trip O-D Interchange Block

A person making a trip for a given purpose generally has a wide choice of destinations. In making a decision as to the actual zone of destination a number of factors are either deliberately or subconsciously considered.

The number of person trips for each of the three basic trip purposes that will be made between one zone and every other zone are calculated by the trip O-D interchange block. For this purpose the block uses the trip interchange equations which include the travel time factors derived in Block 3, and the trip generation and attraction input data.

4. Mode and Route Proportional Split Block

Two functions are performed by this block:

- a. The total person trips calculated to move

between each O-D zone are divided into two groups, those travelling by automobile and those making the trip by transit. To determine the actual number of trips by each mode the travel mode factors derived in Block 2 are used in conjunction with the trip interchange volumes calculated in Block 3.

b. The number of person trips by each mode are next subdivided between the appropriate travel routes constructed by the route generation Block 1. For this purpose route factors derived in Block 2 are used in conjunction with the number of person trips between each O-D pair and by each mode calculated in Blocks 3 and 4 (See (a) above).

The split trips, that is the number of person trips which will proceed via each route and each mode for each O-D pair, are then used as input for the route assignment block to calculate the passenger and vehicle loads on the various links in the area under study.

5. Route Assignment Block

The main function of the route assignment block is to translate inter-zone trip volumes via the various routes and modes into link traffic volumes. Thus, this block traces the routes for each origin to each destination and assigns the appropriate number of O-D trips to each link comprising the O-D routes. Since a link forms part of any number of O-D routes the different O-D "platoons" of trips using each link are summed to give the total person or vehicle flow on each link.

For transit and rail commuter trips these link flows are expressed as the number of persons per hour. For private vehicles link flows are expressed as the number of vehicles per hour. Although the latter can also be shown as persons per hour, the vehicular volumes are required to estimate the

amount of congestion existing on each link and to calculate the average link speed and travel time. Truck trips are generated, distributed and assigned in terms of trucks per hour.

The route assignment block also calculates the parking cost for automobiles in each zone as a function of parking : supply and demand. For this purpose the computer is fed a table showing the number of parking places available in each zone and another table relating the cost of parking in relation to the utilization of these parking places in each zone.

6. Travel Time Block

The travel time block calculates realistic traffic speeds and travel times on all road links, including those with surface transit. This block uses the assigned vehicular traffic volumes in conjunction with empirical formulas which indicate the relationship between traffic volumes and attainable travel speeds.

The results of Block 6 show that on many roads traffic will be slowed down by congestion. In this case drivers will use other routes. A special sub-program, described in detail in the Appendix under the name "Capacity Restraint" has been developed to simulate the choices which drivers are likely to make as a result of congestion; in other words, the proportional division of trips between routes is subsequently changed based on the degree of congestion experienced.

The effects of traffic volumes, in addition to affecting the choice of travel routes also changes the relation between automobile and transit travel time thereby influencing the choice of travel mode. Another effect of changing travel time is that it can either increase or decrease the number of trips between two zones. This changes the number of trips on

the O-D routes which in turn can influence other O-D trips. Thus, a cycle is created based on the influence of travel time.

Operation of the Main Program

The two basic sets of input information, transportation facilities data and land use data, are collected and coded. Transportation facilities data are processed for subsequent use in Block 1 for constructing O-D routes, and Block 6 for calculating link travel times.

Land use data are processed by the trip generation block to produce trip generator and attractor figures for subsequent use in Block 3 for calculating inter-zone trip volumes. Specified land use data are also used in Block 2 for calculating the proportion of trips made by public transportation and by private car between each pair of zones (the travel mode factors), and in Block 5 for calculating vehicle parking costs in each zone.

With the preparation and processing of input data, the main program of the Traffic Prediction Model, Blocks 1 to 6, can begin functioning.

1. Using the Route Generation Block (Block 1) a series of routes are constructed between each pair of zones. Each route is the shortest possible in terms of travel time.

2. The Travel Factors Block (Block 2) estimates the effect these travel times will have on a person's natural inclination to travel for various purposes from one zone to another zone, (trip O-D interchange factors) to use one travel mode instead of another (modal split factors) and to follow one route instead of another (route choice factors).

3. The Trip O-D Interchange Block (Block 3) takes into account these travel factors and opportunities offered for beginning and ending trips in each zone to estimate how many people in total will travel from one zone to another.

4. The Mode and Route Proportional Split Block

(Block 4) uses these total trip interchange volumes and the "modal split factors" of Block 2 to calculate how many people will travel via each mode and via each alternative route from zone to zone (split trips).

5. The Route Assignment Block (Block 5) assigns these "split trip" figures to the pertinent routes to give estimates of traffic flows on all links of each travel mode.

6. The Travel Time Block (Block 6) uses the assigned link volumes combined with the capacity function of each road link to calculate the travel times currently applying to all road links in the network.

Iteration of the Main Program

In general, these new road link times will differ from those on which the previous determination of routes and travel usage were based. It is necessary, therefore, to turn again to Block 1 but using the new link times. Weighted averages of the new route times via all available routes between each origin and destination are then used in Block 2 to calculate new travel factors, leading to a new calculation of zone interchange volumes in Block 3, and so on around the loop through Blocks 4, 5 and 6. This cycle is repeated until equilibrium is reached. This is determined when the link loads and travel times produced by one cycle are not appreciably different from those produced by the previous cycle.

As shown in Plate 2 the six program blocks form a sequential loop. When Blocks 1 to 6 have been run in that order it is possible to return to Block 1 and repeat the sequence. It is by this means that feedback occurs so that the effects of travel time as affected by traffic congestion may be used realistically to influence traffic patterns.

Many of the cycles carried out in a run of the main program will not contain all six program blocks. Possible block sequences in a given cycle shows that the sequential loop

formed by Blocks 1 to 6 can be short-circuited as follows:- Block 3 can be eliminated by going directly from Block 2 to Block 4; Blocks 3 and 4 can be eliminated by going directly from Block 2 to Block 5; and Block 4 can be eliminated by going directly from Block 3 to Block 5.

The meaning of these operations will become clearer if one realizes the purpose of each block. For example, the main purpose of the first few cycles is to produce the desired number of alternative routes between each O-D pair. Experience has shown that reasonable routes can be obtained based on arbitrarily estimated modal split factors and assignment factors, and that it is not necessary to carry out a new trip distribution during each of these route-generating cycles. Consequently, Blocks 3 and 4 can be omitted from most of these cycles with a consequent saving of machine time. Similarly, in the final "settling" cycles when equilibrium is being reached, no new routes are being generated so it is possible to leave part of Block 1 out of each cycle. Experience has also shown that the inter-zone trip volume figures reach equilibrium before the link loads and travel time have completely settled down so that it is possible to "freeze" the trip distribution and leave Block 3 out of the final few cycles.

The flexibility resulting from these alternative sequences is enhanced by a comparable flexibility of input information. For instance, if estimates have already been made of inter-zone travel volumes (by means of a scaled-up O-D survey, say), it is possible to feed these volumes directly into the model, by-pass the time factor, distribution and proportional split blocks and find the assigned traffic flows which would result. This procedure would result in a saving of computing time but would be useful only for short term predictions; over long periods of time, patterns of traffic

congestion in the area could be expected to change considerably, requiring therefore a method of estimating inter-zone travel volumes which will take these things into account. Blocks 2, 3 and 4 in this model have been designed to do so.

The modal split factor percentages, route choice factor percentages, inter-zone trip volumes, link flows, and link travel times produced by the final cycle of a given run describe the predicted traffic pattern for the study area and the time period in question, based on the specified land use patterns and transportation facilities.

3) Output Analysis

a. General Use of Output Data

Having produced this traffic prediction it is possible by inspection to determine which links are most heavily overloaded, which areas are least efficiently served by roads and rail, etc. with a view to proposing new transportation facilities and/or new land use configurations. Having made these proposals the model can be employed again, using the new proposals as input data, to test them for efficiency of operation and to compare them with the original proposals. By this means planning decisions can be made based on systematic appraisal of the various proposed combinations of land use and transportation facilities.

Various other sorts of information describing the predicted traffic patterns can be produced by the model to aid in planning decisions. One such item is the total time spent travelling by all trip-makers during the time period in question, the so-called "system time cost", which is usually measured in terms of person-hours and vehicle-hours spent on routes.

b. "Spider" and "Caterpillar" Programs

The spider program is used to state the origin and destination of each vehicle or person trip using a given road, transit or rail commuter link. The link being studied comprises the body of the 'spider' and the legs extending from both ends indicate the trip origin and destination zones using that link. Thus, given a link of Highway 401 the program takes the vehicular trips assigned to it and states the number of trips coming from each origin and going to each destination.

Data developed by this program are used to assess the value of the link in the routes of which it forms a part and the use of the link in relation to the origin or destination zones and their location to the link.

The caterpillar program traces the 'on' and 'off' movement of traffic using a given facility. The head of the 'caterpillar' is located at a road interchange or rail station and the body is extended along the facility in question. All trips entering the facility at the head are traced to their point of exit along the length of the body. Data obtained from this program permits a study of the use of the facility in relation to trip lengths and traffic volumes at entering and exit points.

c. Standard Output of Traffic Prediction Model

The standard output may be summarized as follows:

1. Topographic Tree by a given travel mode describes the routes (link by link) from a specified origin zone node to all destination zone nodes. New topographic trees via a given travel mode are generated during subsequent cycles of the Route Generation Block.

2. Time Tree by a given travel mode reports the

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travel times from a specified origin zone node to all destination zone nodes via each route described by the topographic tree.

3. Number of person departures from each zone node by travel purpose.

4. Number of person arrivals at each zone node by travel purpose.

5. Number of person departures from each zone node by travel mode.

6. Number of person arrivals at each zone node by travel mode.

7. Person trips by travel route and mode between each origin and destination.

8. Person trips by travel purpose and mode between each origin and destination.

9. Total travel time reports the number of vehicle and person hours spent travelling by all users within the time period under study:

- (a) for automobiles in vehicle-hours.
- (b) for auto travellers in person-hours.
- (c) for transit travellers in person-hours.
- (d) for trucks in vehicle-hours.

10. Link load and Time data (reported for each link)

- (a) Length of link in miles, number of lanes, and link capacity.
- (b) Auto travel time reports the average time in minutes required for an automobile to travel the length of the link under prevailing traffic conditions.
- (c) Auto travel speed for each link.
- (d) Traffic volume with and without transit vehicles.

- (e) Traffic volumes shown as either; below critical flow, between critical and maximum flow and exceeding maximum flow.

If the traffic volume is below the point of critical flow, the road section is operating in the "free flow" region; if the traffic volume is between critical and maximum volumes, the road section is operating in the "turbulent" region; and if the traffic volume exceeds the maximum flow, the road section is operating in the "overloaded" region. (See Capacity Function Curves - Appendix II Route Assignment)

- (f) Transit travel time.
- (g) Transit travel speed.
- (h) Number of transit vehicles per hour.
- (i) Number of transit passengers per hour.
- (j) Number of transit passengers per transit vehicle.
- (k) Truck travel time.
- (l) Truck travel speed.
- (m) Number of trucks per hour.

11. Turning movements: the number of auto, truck, or transit vehicles making left and right turns and straight through movements at specified intersections.

12. Spider movement reports for specified links, the auto, truck or transit link loads by trip origin-destination and reports the interchange travel times of these interchanges affected.

13. Caterpillar movement reports the turning movements at each interchange along a given facility and the trip lengths along the facility of all travellers entering at each interchange.

III. VALIDITY TEST OF THE TRAFFIC PREDICTION MODEL

It has been shown that the Traffic Prediction Model is essentially a series of computer programs each of which represents different aspects of persons' travel characteristics. The mathematical formulas used in each program are as accurate as presently possible in their ability to predict those particular characteristics.

Although each program block is subjected to individual tests to determine their ability to provide predictions within acceptable statistical error limits the complete model requires that the main program blocks be linked together in a sequential operation. This is an essential feature of the model which combines the various effects that travel time has on a number of travel decisions.

For a full scale test of the model it was decided to use the year 1956. This year was chosen because the essential input data were readily available as well as the observed traffic flows required to compare against the 'simulated' traffic flows produced by the model. Coincident with the validity test it was also necessary to establish the most efficient procedure of operating the various program blocks so as to minimize the amount of time required to reach settlement.

Transportation Grid, Input Data and Observed Data

a. Transportation Grid Data

Plate 3 shows the abbreviated transportation system represented by 1,778 links and 570 nodes.

Each link represents a section of one or more roads

or transit routes. A link may therefore represent up to nine lanes by adding the lanes of adjacent parallel roads classified as arterials or major collector roads.

The solid line indicates that at 1956 the link was used by both private and public transit vehicles while the broken line signifies that public transit service was not available.

At a number of points in the grid two or more nodes with short connecting links are shown in place of single intersection nodes. This was required to indicate the points of transfer between transit routes and to add a transfer penalty for such transfers.

Rail commuter service was almost non-existent in 1956 so was not included in the transportation grid. The Yonge Street subway between Union Station and Eglinton Avenue was opened in the early part of 1954, and was included in the grid. Subway stations are shown by a square and with a 'T' following the node number.

Because the necessary input data were not available for areas outside the Metropolitan area, external nodes numbered 283 to 295 were given the number of vehicles inbound during the two-hour a.m. peak period as reported by the External Traffic Survey in 1955. These vehicles were distributed to destination zones within the area by the trip O-D interchange block. The links connecting these external nodes to the next adjacent internal nodes were given various lengths considered average for these external trips.

Table 2 lists the link input data. Each link is listed once only unless the two travel directions of the link have significantly different operating characteristics.

b. Land Use Input Data

Plate 4 shows the Metropolitan area sub-divided into data zones numbered 1 to 295. Table 1 lists the input data of each zone.

Since most transportation grid nodes also represent zone nodes, the size of each zone is mostly determined by the distance between the grid nodes. In the areas of high trip density the links and nodes representing the grid are close together, becoming further apart with decreasing density away from the Central Business District. Although zone size is not deliberately based on trip density they are nevertheless shown to be closely related.

c. Observed Traffic Data 1956

Each year various traffic agencies undertake traffic counts throughout the Metropolitan area. For the purpose of assessing the accuracy of the computer model the following traffic flow volumes observed in 1956 have been used:

The Ontario Department of Highways, throughout 1956, made a year long study of two-way traffic volumes at many points along the Highway # 401 in Metropolitan Toronto. These data have been used to determine the average hour traffic volumes of the two-hour a.m. peak traffic as well as to study traffic fluctuations occurring, both all day and during the peak hours.

The Toronto Transit Commission each year counts the vehicles, persons and persons in vehicles, crossing fixed traffic barriers referred to as 'cordon lines'. The cordon lines used for comparative purposes are shown on Plate 3. Unfortunately on some cordons the usual counts were not undertaken during 1956 so that data recorded in 1955 and 1956 have been used.

Passenger riding counts were also available for each station to station section of the Yonge subway. In the absence of data to determine the daily passenger volume fluctuations between stations of the Yonge subway, these have been estimated based on observed vehicle traffic volume fluctuations (Plate # 8). In addition to the Highway # 401 traffic studies, excellent traffic flow data was obtained from the electronic computer traffic signal study made in the Eglinton Avenue/Bathurst Street area.

Error Limits of the Model

To justify its use for the study of future traffic demand and the development of a transportation plan, it was necessary to determine the ability of the Traffic Prediction Model to predict travel characteristics to a sufficient degree of accuracy.

In 1956, during the average hour of the two-hour a.m. peak period, there were approximately 250,000 person trips made within the Metropolitan area. The model was used to simulate how these persons distributed themselves throughout the area, for what purposes, by what means and by which routes. At 'settlement' the resulting traffic volumes on certain links were compared with the traffic volumes reported by observation in 1956.

There are a number of possible sources of error in the total operation. These can be considered in three parts.

1. Accuracy of the input data; land use and description of the transportation facilities.
2. Accuracy of the observed data used to compare the simulated traffic volumes.
3. Accuracy of mathematical formulas and empirical relationships used in the model.

1. Accuracy of Input Data

a. Land Use Data

Although it may be humanly possible, it would not be economically feasible to describe in complete detail the type and extent of the total land uses and the activity of the Metropolitan area. These characteristics of the area are of necessity described in a broad manner and are distributed in a relatively coarse array of zones of various sizes.

Since traffic is motivated by these land uses, it must be assumed that some simulation error is caused by the coarseness of the land use data used in the model. It must also be recognized that since the basic description of the total area is necessarily coarse, extreme accuracy of predicting traffic flows on individual low capacity links of the road and transit facilities could not be reasonably expected. In the test study 295 zones only were used although 500 zones are used for the prediction studies.

b. Transportation facilities

The transportation grid takes into consideration the traffic significance of all roads that could be considered to have some value as a through road.

Under heavy traffic conditions many local streets not included in the grid would be used by some traffic attempting to by-pass congested locations. It is not possible to include in the grid the capacity of the entire street network and it would, in fact, be extremely difficult to determine the traffic capacity of these local streets.

Although some error can be attributed to the design of the transportation grid, provision is made in the model to exclude a percentage of the short intra-zone trips on the

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assumption that they could be made on local streets.

To compensate for the coarseness in describing the transportation facilities the total trip generation of each zone has been reduced by some percentage to account for the short local trips that would occur on local streets.

2. Accuracy of Observed Data

Most traffic volumes used in the comparative analysis were observed for one weekday only of the year. Although it is usual to undertake traffic counts during those months where volumes are considered average for the year, there is nevertheless no reason to suppose that the observed figures represent true averages. Weather conditions, road works forcing traffic to other routes, traffic accidents or unexpected congestion close to a counting station etc. would affect observed traffic counts. Similar reasons could also affect subway riding counts.

Although all observed traffic data are referred to as representing average weekday flows, it should be remembered that these figures are not true averages and therefore should not be rigidly assumed as such when compared against the simulated volumes.

3. Accuracy of Mathematical Formulas and Empirical Relationships

All mathematical formulas and empirical relationships used to predict average travel behaviour characteristics have been based on the results of factual surveys. These formulas are used in the various program blocks, each of which is subjected to a series of tests to ensure their statistical reliability in relation to the function they perform.

Comparison of Observed vs Simulated Traffic Volumes

a. Travel Time Chart

Plate 5, the auto and transit travel time chart, represents a record of the total travel times of auto and transit passengers at the end of each iteration of the main program. The first few iterations show high travel times caused by congestion on the routes initially constructed. As new routes are generated travel times decrease and the travel decisions of trip destination, travel mode and route choice, tend toward equilibrium. This is shown by the last two iterations where the fluctuations of two travel time lines have levelled off to a point where it can be considered that settlement has been reached. Although additional iterations would show some change the total variation would not be significant.

b. Trip Distribution Travel Time Comparison

Plate 6 shows the cumulative percentage distribution of auto and transit trips in terms of travel time. The solid line represents the observed frequency distribution as derived from the Home Interview Survey 1956. The broken lines represent the simulated distribution reported by the first, an intermediate and the final iteration of the program. The observed and final simulated settlement for the total trip distribution shows exceptionally good agreement well within acceptable error limits.

In the initial distribution trip travel times were relatively short due to traffic congestion on the limited routes available, hence the broken line is shown to the left of the solid line which represents the observed distribution.

An intermediate frequency curve is shown to demonstrate the oscillation that occurs between the first to last iteration.

At this point a higher percentage of longer travel time trips are reported.

At the point of settlement on the traffic system, the frequency curves for both modes are shown to correspond closely with the observed data.

c. Highway # 401

Plate 7 compares the observed and the simulated vehicle volumes in both directions on Highway # 401. At 1956 only that section between Highway # 27 and Bayview Avenue was open to traffic.

A year long traffic study of Highway # 401 traffic by the Ontario Department of Highways shows that traffic volumes fluctuate considerably both all day and during peak traffic periods. The shaded area (Plate 7) centred about the line representing the observed traffic flow indicates the range of traffic fluctuations known to occur during the simulation study time period. The degree of fluctuation is shown to vary in accordance with the traffic volumes generally experienced. Thus, where high volumes occur on the average the fluctuation is relatively less pronounced than where lower volumes are normally experienced.

Westbound Traffic

The simulated vs. observed westbound traffic volumes are shown to compare most favourably between Bayview Avenue and Islington Avenue. In this section the simulated volumes fall within the shaded area indicating results well within statistical error limits. West of Islington Avenue the simulated traffic volumes are about 30% higher than those observed.

Eastbound Traffic

The eastbound traffic flows are also shown to agree

very closely with the simulated traffic. The only location showing a poor comparison occurs between Weston Road and Islington Avenue.

Since the simulated traffic on Highway # 401 is shown to compare most favourably with observed traffic volumes in all but a few sections, it is concluded that the larger discrepancies result both from the description of traffic facilities and the coarse arrangement of zones in those areas.

In the more heavily loaded central section the higher simulated volumes could be accounted for by short trips using Highway # 401 because parallel local streets are not sufficiently represented in the transportation grid.

d. Yonge Street Subway

Plate 8 shows in solid line the observed passenger volumes on the Yonge subway compared to the simulated volume shown by a broken line. The shaded area centred about the observed line indicates the extent of the estimated weekday average peak hour fluctuations. As previously explained these station to station fluctuations are derived from studies of vehicular traffic volume fluctuations.

The observed riding count cannot be considered as an absolute weekday peak hour average since counts are not taken on a sufficiently regular basis. However, since more accurate data are not available, they must be considered as sufficiently valid for this comparative study.

The largest discrepancy is evident south of Queen Street. Between Queen and King Street stations the simulated volume is about 5,000 passengers above the observed and below King station the passengers are shown about 2500 passengers lower than observed. These discrepancies are balanced out at

Queen Street. The low volume at Union Station was caused by two conditions; one instead of two roads were connected with the station, and that only one data zone lies close to the station. Thus, heavier volumes enter the line at King Street.

The comparison indicates that the model is able to provide predictions of rapid transit passenger flows to a high level of accuracy not possible by other presently known means of traffic simulation.

It is also worthy of mention that the model estimated that of all person trips made within the study time period, 46% would use public transit. Expanded sample trips of the Home Interview Survey reported 45.5% transit users.

e. Intermediate Cordon Line

Plates 9 to 14 illustrate the simulated and observed vehicle and transit passenger volumes crossing the three sections of the Intermediate Cordon Line. Traffic fluctuations are not represented on these plates. The traffic at each individual cordon crossing point is shown by travel direction. The following table summarizes the traffic crossing each cordon section and the total volume of the entire cordon line.

The simulated outbound vehicles are about 16% higher than the observed while the transit passenger volume is only 2% higher. On the other hand, outbound simulated traffic is lower than the observed volumes being most pronounced in relation to the low volumes of auto/truck traffic. Except for the outbound auto/truck traffic crossing the Don Valley and North Toronto cordons the simulated results fall within the observed traffic volume variability.

Simulated vs. Observed Traffic Crossing Intermediate Cordons

Average hour of two-hour a.m. peak

<u>Inbound</u>	<u>Autos and Trucks</u>			<u>Transit Passengers</u>		
	<u>Observed</u>	<u>Simulated</u>	<u>% Diff</u>	<u>Observed</u>	<u>Simulated</u>	<u>% Diff</u>
Allandale	7,800	9,400	+20	12,700	13,000	+ 2
North						
Toronto	11,100	12,200	+10	24,300	22,000	-10
Don Valley	8,300	10,000	+20	18,200	21,400	+18
Totals	27,200	31,600	+16	55,200	56,400	+ 2

Outbound

Allandale	4,400	3,800	-14	5,000	4,700	- 6
North						
Toronto	4,900	3,500	-30	6,700	6,200	- 8
Don Valley	3,200	1,700	-47	3,100	2,700	-13
Totals	12,500	9,000	-28	14,800	13,600	- 8

Cordon Segments

Individual segments of the cordon line comprise the Allandale, North Toronto and Don Valley cordons shown on Plate 3.

a. Auto/trucks crossing cordons

A close fit is registered between the comparative east-bound traffic flows crossing the total Allandale line; the difference being about 2,000 vehicles or, plus 20% over the observed. However, the percentage errors on individual road links show variations from -6% on the Lake Shore to +46% over observed volumes at King, Bloor/Wallace and Dupont.

It is significant that the high capacity Lake Shore Road carrying 42% of total cordon traffic shows an insignificant comparative error. It would then appear that the majority of the total cordon difference is concentrated in the east-west

corridor north from Dundas Street where a +40% difference is shown.

In the reverse travel direction total crossings also compare favourably. The large difference apparent on the Lake Shore Road could have resulted from the description of the grid. At 1956 the four-lane section of the Lake Shore Road was operated with 3 traffic lanes in the peak flow direction and 1 lane in the reverse direction.

Link crossings for both the North Toronto and Don Valley cordons show similar ranges of percentage difference. In some instances, such as Dufferin, Ossington and Bathurst, on the North Toronto line, the simulated volumes compare favourably with the observed when considered in travel corridors comprising two or more adjacent links.

b. Transit passengers crossing cordons

Plate 10, which shows the transit link loads crossing the Allandale cordon also emphasizes the adequacy of analyzing traffic movement in comparatively narrow travel corridors. This is also evident on the Don Valley crossing, where an extremely close prediction between the comparative volumes on Queen Street is also shown.

On the North Toronto cordon the simulated Bathurst transit riding is substantially higher while the Yonge subway riding is shown to be lower than the observed volume. A study of this deviation indicated that the excess volume on Bathurst would have used the Yonge subway at transit transfer points on Bathurst north of the cordon line being adequately represented. In all instances the transit travel in the opposite direction is shown to compare most favourably.

Summary of Comparative Analysis

When comparing the observed values against those produced by the Traffic Prediction Model it should be kept in mind that the latter tends to produce flow volumes at the state of equilibrium. In a transportation system at equilibrium no participant can improve his travel without exercising a corresponding amount of impedance on the other participants. On the other hand, equilibrium is never achieved under actual traffic conditions. Basically some proportion of all travel is always unstable. The observed values therefore are representative of a traffic system which is to some degree in a state of flux. This is supported by studies made of traffic volume fluctuations observed on Highway # 401 and Eglinton Avenue.

It has been shown that the simulated test was brought to a satisfactory settlement so that all trip decisions were made and traffic facilities loaded in relation to their capacities. Trips distributed themselves by travel time between all O-D pairs to reproduce closely the trip distribution function observed in 1956. Total trips by travel mode were simulated almost to coincide with the observed total.

The comparison between observed and simulated traffic volumes indicates that prediction figures for expressways and rapid transit are well within error limits and provide sufficiently reliable data to justify their use for planning purposes.

The less reliable prediction of link loads on lower type facilities requires that they be considered in groups to form travel corridors rather than used for individual link load analysis.

The reason why considerable prediction accuracy is achieved for high-type facilities, with lesser accuracy for lower-type facilities, is readily explained. Expressways and rapid transit facilities are far more efficient in their operation because many frictions that are most evident on other facilities are avoided. Also, these trunk facilities are not affected to the same degree by the coarse description of the study area. Consequently, their operating characteristics and traffic use are more readily predictable than on less efficient facilities.

The latter have a wide range of factors that affect their operation, such as the number and timing of traffic signals, pedestrian traffic, traffic generated by frontage development, number of access points, etc. Thus, on facilities with these characteristics a large combination of factors create frictions of various magnitudes, thereby making their use more difficult to predict. The development of more efficient computers with larger storage capacity than presently available will enable greater accuracy to be achieved in all parts of the prediction model, particularly on links carrying relatively small traffic volumes.

IV. APPLICATION OF THE MODEL

Types of Application of Model

The possible applications of the model for testing the probable effect of proposals are practically unlimited. In all cases the model simulates the traffic flows which would occur under specific assumed conditions. The proposals which can be tested in this manner can be divided roughly into three groups:

1. proposals for new or improved traffic facilities, such as roads, road widenings, subway lines, commuter parking lots, etc.

2. proposals for changes in operation, such as restriction of street parking, prohibition of left turns, changes in parking fees and changes in fares or level of service in the case of transit and commuter railroads.

3. proposals or changed predictions for land use, such as land use in years prior to or after 1980, or for residential subdivisions, new industrial plants, shopping centres, etc. or for higher or lower levels of density.

By isolating and analyzing data produced in the process of traffic simulation it is possible to determine where pressures for land development are likely to be higher or lower than assumed in the original land use plan, indicating the advisability of making changes in that plan and in zoning by-laws based on the land use plan.

Necessity to Limit the Number of Applications

Use of the model to study a hypothetical plan of

transportation facilities such as that contained in the Draft Official Plan of the Metropolitan Toronto Planning Area invariably leads to further studies being made to determine the effects of either adding to or subtracting from the initial plan. Since the total system comprises three major elements, expressways, rapid transit and rail commuter, each of which can be broken down into any number of sections, it is possible to derive a gigantic permutation of hypothetical systems for individual study. In addition to the large number of system studies it would also be necessary to determine the effects of changing a number of critical variables that are known to influence travel behaviour characteristics.

The experience gained with the model has shown that to proceed with the testing of all such possible alternatives and variables, while technically feasible, would require an excessive amount of time and money. Also, the volume of data that would be produced would be almost impossible of analysis to decide on the best total system.

Proposed Applications of the Model

A method has been developed to eliminate, by a series of rough preliminary tests, a great number of possible proposals as unworthy of detailed study, and thus to delimit the range within which alternatives will be accepted as worthy of complete testing.

Simplification of study area

For this purpose a simplified transportation grid will be used, employing only 100-150 zones and some 250 nodes instead of over 400 zones and 600 nodes required in the complete model, and broad channels of movement in place of detailed alignments of road and transit facilities. This simplified

model will determine the general levels of demand for private and public transportation, respectively, in Metropolitan Toronto. This will be done by assuming maximum facilities for public transportation and then in successive steps, increasing facilities for private transportation from a minimum to a maximum and vice-versa.

Study of critical variables

To determine the influence exerted by certain critical variables on travel behaviour characteristics, it is proposed to use the model to study six variables. The transportation system and land use input data are fixed and, one at a time the value of each variable is gradually changed over a predetermined range of values. Information extracted from various program blocks are then compared against the variable being tested and a range of effects accumulated for each. For example, to determine the significance of transit fares on transit riding the model is used to predict transit riding assuming a range of transit fares from zero to 50¢ or more. Similarly the effect of the availability of transit service can be studied by assuming different spacing of routes and different times between transit vehicles.

The six variables to be tested are:

- (a) Public transit fare structure
- (b) Parking charges
- (c) Vehicle operating costs
- (d) Transit speeds
- (e) Headway or availability of service
- (f) Route spacing for transit (walking distance)

Development of a balanced transportation system

The result of the above studies will enable more realistic assumptions to be included in the model for use in establishing the optimum point of balance between roads, rail

and transit facilities. By using the simplified description of the area with broad corridors of movement rather than exact alignments and design characteristics of facilities, the results will show the level of demand for each system in each corridor. Studies of these results will show that a great number of proposals for facilities in these corridors are not warranted and can be eliminated without further study.

Once the range of possible alternatives has been narrowed by this method, detailed studies can be made using the maximum number of zones and nodes. The result of these studies will determine the final system of transportation facilities to be included in the Official Plan for 1980.

Further Applications of the Model

Following the presentation of this plan a second series of studies will commence as soon as data from the 1961 census and of current studies of industrial development have become available, and a projection of land use for 1970 has been developed on the basis of these data. They will simulate the traffic volumes likely to occur in 1970 on each link of the final system of transportation facilities adopted for 1980 and show which of these facilities will be most urgently required already in 1970 and therefore should be included in the 10-year capital budget.

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

Node	Population	Dwelling Units	Residential Acres	Cars	Total Employment	Wholesale Employment	Retail Employment	Income (Economic Indicator)	Units of Transit Line 1 unit = .01894 mi.	Parking Cost \$X.XX	Transit Stop Spacing in miles
1	5652	1526	154	1238	1469	24	525	2887	43		17
2	2845	727	99	662	841	44	200	2982	43		17
3	6403	1813	220	1362	1992	36	627	2856	51		17
4	2667	752	56	635	1558	29	761	2888	23		17
5	7444	1927	126	1772	8533	28	2012	2886	41		17
6	2073	602	43	518	1016		861	2975	26		17
7	7685	2428	179	1922	2021	115	798	3082	107		17
8	807	209	24	188	2208	240	771	2911	122		17
9	3929	957	90	957	2138	17	1380	2830	50		17
10	2100	506	99	457	3598	442	330	2813	96		17
11	6564	1574	230	1527	1050	66	139	3041	67		17
12	3614	840	214	845	1341	104	415	2977	110		17
13	2244	603	66	534	1465		83	3292	45		17
14	5333	1364	99	1333	163		151	3134	41		17
15	3200	749	167	841	1220	104	580	3038	102		17
16	5173	1549	139	1478	146		75	3211	104		17
17	499	128	28	143	114	18	33	2852	1		17
18	8700	1813	100	1673	8061	819	2123	2554	63		13
19	94	25	70	21	2335		2148	3292	73		17
20	7421	1937	367	1889	246		243	3557	106		17
21	1946	503	78	556	163		151	3134	43		17
22	5109	1501	101	1460	80		64	4234	23		17
23	2826	875	102	807	389	9	356	5095	81		17
24	3872	1076	155	1291	1722	305	856	3185	49		17
25	8785	2566	360	2929	1047	36	910	4939	170		17
26	2388	669	126	682	1504		1192	3835	135		17
27	5803	1752	270	1584	232		232	4830	82		17
28	3438	955	206	1141	270	3	214	5353	86		17
29	989	248	111	330	67		67	5353	33		17
30	3166	817	169	904	77		77	3553	1		17
31	2532	648	181	666	67		62	3775	54		17
32	3321	873	215	906	88		83	3208	30		17
33	2544	557	9	424	7140	355	4435	2000	91	83	13
34	608	153	73	174	38		38	3569	62		17
35	383	100	142	109	189		171	3349	34		17
36	3726	976	190	932	229		188	3349	93		17

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

Node	Population	Dwelling Units	Residential Acres	Cars	Total Employment	Wholesale Employment	Retail Employment	Income (Economic Indicator)	Units of Transit Line 1 unit = .01894 mi.	Parking Cost \$X.XX	Transit Stop Spacing in miles
37	1148	298	53	328	165		131	3349	52		17
38	907	238	120	259	18		18	3569	32		17
39	7023	1026	46	1048	1544	29	512	2393	61		13
40	3469	541	26	456	6885	621	3050	2197	81		13
41	356	89	25	101	281		128	3030	63		17
42	3135	715	242	809	1191		263	3136	93		17
43	20	5	7	6	2828	108	302	3140	1		17
44	7551	1928	235	1962	423	122	41	2464	1		17
45	439	113	94	126	43		43	2346	1		17
46	2796	710	211	759	360		360	2854	44		17
47	1352	167	35	193	6393	472	4538	2000	75	108	13
48	2432	574	200	577	1911	74	728	3167	55		17
49	8494	2059	455	2030	889		667	3187	52		17
50	4419	1200	200	1105	1676		855	3194	69		17
51	4232	1029	169	1175	2215	25	1483	2960	92		17
52	5702	1519	168	1584	2831		1545	3013	39		17
53	5736	1349	286	1471	386		332	3145	106		17
54	2211	481	115	515	1801	5	334	2976	49		17
55	12199	3346	438	2744	1909	50	1689	3661	147		17
56	1677	422	35	466	1198	25	578	3050	56		17
57	1610	438	32	447	1198	25	578	3050	44		17
58	2606	607	125	668	495		428	3145	52		17
59	6160	1435	199	1732	2563	175	1042	3044	76		17
60	2199	539	79	579	132	1	81	3478	21		17
61	2289	652	84	715	209	30	153	3860	67		13
62	2507	468	14	374	3035	253	222	2365	39		13
63	1050	266	25	210	712	190	19	2436	13		17
64	8437	2112	139	1623	1327	14	1030	2862	81		17
65	4371	1095	77	970	3097	61	1445	2780	21		17
66	18233	4883	280	4007	4288	141	2406	2939	125		13
67	2535	691	56	650	472	7	445	4912	47		13
68	2118	554	34	460	547	35	512	2759	57		17
69	5945	1561	170	1443	5648	490	1003	3235	117		17
70	3995	1062	165	1129	302	21	183	3629	57		13
71	5610	1381	125	1317	925	10	685	2992	87		17
72	11182	2895	183	2452	3210	101	1448	2795	123		17

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

Node	Population	Dwelling Units	Residential Acres	Cars	Total Employment	Wholesale Employment	Retail Employment	Income (Economic Indicator)	Units of Transit Line 1 unit = 01894 mi.	Parking Cost \$X.XX	Transit Stop Spacing in miles
73	4069	1016	55	904	398	67	250	2732	21		13
74	4257	1246	55	922	587	21	503	3184	54		13
75	10128	3086	247	2491	641	11	593	3520	100		13
76	3802	968	80	915	1073	31	566	2729	94		17
77	3298	820	52	750	963	41	584	2833	50		17
78	7230	1706	100	1502	9454	165	1785	2671	133		13
79	3136	713	40	581	608	71	368	2638	32		13
80	13411	3085	144	2442	1599	49	819	2732	76		13
81	8427	2134	114	1505	740	4	604	2837	89		13
82	9233	3228	134	1976	648	5	562	3194	135		13
83	6764	1417	55	995	5099	139	2519	2720	97		13
84	10256	2169	115	1831	1505	36	1357	2748	117		13
85	9748	2136	121	2166	3396	76	2059	2762	93		13
86	4548	1200	72	1011	4893	170	3980	2752	97		13
87	3336	891	48	758	473	22	451	2832	67		17
88	2674	526	24	535	1229	69	608	2436	53	50	13
89	3049	1034	46	462	776	13	377	2604	37		13
90	9884	3602	231	2512	1845	318	551	3148	108		17
91	11616	3115	214	2778	975	51	683	3055	109		13
92	4541	984	77	908	178	1	173	2819	17		13
93	9877	2084	82	1619	7700	81	2007	2570	86		13
94	6880	1463	65	1128	1021	63	678	2592	33		13
95	7156	1507	69	1084	1934	85	902	2624	72		13
96	5554	1173	45	842	924	73	524	2514	36		13
97	2258	626	77	627	860	125	211	3160	56		13
98	5485	1275	55	1192	2241	260	1134	2653	69		13
99	10989	2239	98	1962	5304	192	1564	2441	114		13
100	7278	1538	86	1300	1411	66	1220	2497	54		13
101	3623	936	19	739	8991	752	7035	1982	117	75	13
102	6666	1069	62	966	1071	33	887	2424	58		13
103	5003	1114	50	834	849		375	2484	43		13
104	7782	1454	75	1297	3411	37	1626	2521	59		13
105	4560	995	30	814	2578	76	600	2586	55		13
106	8523	1535	74	1272	1035	22	759	2474	74		13
107	6214	1065	43	927	2110	187	748	2376	58		13
108	6691	1182	52	999	3425	157	1303	2485	79		13

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

Node	Population	Dwelling Units	Residential Acres	Cars	Total Employment	Wholesale Employment	Retail Employment	Income (Economic Indicator)	Units of Transit Line 1 unit = .01894 mi.	Parking Cost \$X.XX	Transit Stop Spacing in miles
109	692	119	5	99	5453	303	725	2249	20		13
110	614	173	16	205	608		541	2700	34		13
111	2515	620	252	699	213		122	2852	1		17
112	3832	948	267	1198	154		138	3026	7		17
113	61	5		12	28460	2447	21367	1980	45	150	13
114	5586	1418	359	1554	188		170	2905	36		17
115	3562	882	216	989	185	3	146	3196	1		17
116	3322	895	180	898	124	2	98	3196	41		17
117	6509	1699	374	1760	1279	35	685	3172	65		17
118	5517	1504	265	1549	870	22	466	3563	43		17
119	10804	2997	337	3138	1392	24	945	3509	64		17
120	2232	586	83	603	650	10	538	3196	29		17
121	7792	1899	403	2060	284	99	138	3270	75		17
122	600	125	117	187	2260		1015	3139	12		17
123	4445	1033	131	1111	3106	11	369	3509	56		17
124	6130	1607	208	1572	138	54	57	3436	66		17
125	1852	479	53	529	69	27	29	3436	103		17
126	3946	954	149	1161	65		45	4679	84		17
127	2520	743	152	813	38		20	4322	48		17
128	1701	528	90	587	138	3	86	5028	87		17
129	4305	1261	89	879	550	4	497	2797	58		13
130	7550	2336	367	2077	744	42	564	3858	145		17
131	1524	409	184	610	36		36	3973	55		17
132	5113	1515	159	1278	855	42	678	3860	100		13
133	10218	3179	200	2085	593	6	543	2880	87		13
134	11792	3514	283	2771	2561	77	1864	3199	139		13
135	2636	754	109	694	196		196	6755	28		13
136	7046	2354	184	1904	615	10	593	4058	112		13
137	3213	1084	141	803	256	2	254	5195	90		13
138	2828	807	287	943	2193		2117	4408	56		13
139	6892	2187	155	1792	1410	570	727	4615	85		13
140	3696	1173	75	973	335	8	292	4056	46		13
141	5078	1165	101	1372	1112	139	952	3016	75	50	13
142	1892	485	54	573	292	4	248	4354	40		13
143	1641	396	80	497	584	14	560	3834	1		13
144	6159	2175	129	1665	1835	69	1735	3836	108	75	13

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

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145	6965	2043	120	1620	3317	617	2264	2878	128	75	13
146	11242	3244	223	2614	1953	84	1447	2999	139		13
147	3361	1052	81	1018	584	8	496	4354	50		13
148	7318	2254	174	2218	2951	720	1896	3505	56		13
149	10590	3738	282	2737	1645	68	1396	3376	119	120	13
150	5451	1791	95	1297	5432	743	4537	2659	90	120	13
151	5419	1577	169	1355	760		760	4075	74		13
152	3487	1092	82	1057	584	8	496	4354	36		13
153	838	177	6	246	5448	367	4751	2126	52		13
154	1658	468	377	500	180	30	65	5260	41		17
155	6484	1350	63	1081	3078	158	627	2518	57		13
156	7024	2003	258	2363	1218	61	137	2864	208		17
157	6547	1331	80	1423	1643	56	1424	2629	75		13
158	2906	779	104	938	1243	61	112	2623	140		17
159	727	171	59	242	1041	409	95	2742	139		17
160	4552	1177	159	1148	144	20	36	3110	107		17
161	8248	1817	121	1793	1035	11	538	2670	133		13
162	3240	785	162	926	43	8	19	3116	27		17
163	5723	1457	272	1431	47		47	3116	1		17
164	14997	3938	562	4059	1375	29	416	3116	217		17
165	418	128	18	105	1307	20	377	3116	81		17
166	14813	3796	376	3446	2895	190	699	2879	219		17
167	3957	1039	71	879	740	26	154	2755	89		17
168	2403	605	94	601	1478	50	306	2755	47		17
169	3280	771	110	763	1323	120	225	2755	39		17
170	10565	2770	299	2401	1410		875	2872	101		17
171	5844	1140	62	991	537	9	516	2380	47		13
172	5723	1408	291	1301	609		499	3018	66		17
173	5066	1265	403	1407	325	3	318	3748	111		17
174	494	127	209	141	34		19	2927	1		17
175	2044	551	274	568	78	2	67	2832	88		17
176	418	117	33	121	2		2	2814	1		17
177	828	218	79	223	45		45	2941	28		17
178	7962	2054	630	2073	73		58	3005	191		17
179	6955	1731	307	1656	92		92	3116	117		17
180	4152	856	55	830	3633	73	3434	2567	52	50	13

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

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181	1635	429	74	372	152		125	3018	35		17
182	4473	1166	628	1350	113		75	3083	1		17
183	4044	1058	742	1239	319	4	229	3161	1		17
184	746	182	86	221	48		48	2634	1		17
185	711	181	78	229	32		32	2832	2		17
186	5275	1343	687	1622	207	3	182	2834	99		17
187	4685	1280	909	1361	672	2	125	2843	35		17
188	575	149	46	173	4		4	2696	1		17
189	9708	2865	223	2128	1366	79	693	3335	155		13
190	8537	2457	112	1541	1317	108	1131	2681	76		13
191	8155	2196	84	1431	1760	4	1038	2450	72		13
192	9092	2248	63	1281	2787	342	1212	2390	94		13
193	1205	298	15	188	5553	147	1333	2404	69		13
194	7077	1996	69	1011	5983	62	361	2389	76		13
195	7790	1745	83	1406	2075	84	1386	2588	91		13
196	10518	2640	121	1899	1337	30	1249	2621	58	50	13
197	4194	1100	73	856	450	3	406	2797	43		13
198	4318	1416	127	1136	694	70	621	3269	71		13
199	3132	892	106	871	603		333	3176	53		17
200	8802	2388	144	2316	783	60	686	2779	64		13
201	7187	1937	131	1562	937		932	2662	54		13
202	12858	3444	161	2594	3362	91	2456	2662	91		13
203	11734	3028	149	2407	3418	127	2513	2807	99		13
204	4761	1161	51	992	1217	93	883	2752	35	50	13
205	9028	2376	234	2333	2056	110	1344	2838	116		17
206	4122	1037	55	877	531	4	401	2430	43		13
207	5830	1405	91	1240	842	230	255	2836	57		13
208	4278	1093	55	972	324	6	234	5694	36		13
209	7170	1735	126	1630	843	7	568	2724	103		13
210	6831	1990	163	1518	1614		1472	3312	32		17
211	4563	1344	107	1141	690	4	654	3148	38		17
212	3594	1227	50	705	277	3	217	2878	38		13
213	9243	2209	118	1651	733	5	522	2687	109		13
214	103	18	2	17	852	157	547	2878	28		13
215	8018	1939	110	1706	1087	43	506	2560	72		13
216	4612	903	57	904	1338	153	999	2585	55		13

TABLE 1 — LAND USE INPUT DATA FOR 1956 TEST RUNS

Node	Population	Dwelling Units	Residential Acres	Cors	Total Employment	Wholesale Employment	Retail Employment	Income (Economic Indicator)	Units of Transit Line 1 unit = .01894 mi.	Parking Cost \$X.XX	Transit Stop Spacing in miles
217	5747	1279	80	1127	2572	146	2012	2414	66		13
218	3844	933	23	620	3144	114	2910	2209	68	75	13
219	7793	1771	99	1371	3981	27	3234	2395	76		13
220	6614	1184	54	987	2451	76	1863	2476	79		13
221	292	59	3	44	4286	18	3834	2227	84		13
222	3141	1242	21	499	2571	93	2373	2209	46	75	13
223	5667	1558	49	810	1018	26	703	2329	54		13
224	8261	1664	79	1589	2458	472	958	2383	89		13
225	5143	948	38	677	10163	454	8678	2143	91		13
226	565	147	89	165	116		106	3067	1		17
227	6838	949	47	977	1938	752	1072	2141	88		13
228	5726	930	35	753	3756	630	2511	2216	76		13
229	9282	2022	85	1326	2459	488	378	2378	80		13
230	4393	810	40	578	4313	326	2105	2188	74		13
231	6627	1456	109	1325	2332		658	2837	47		13
232	2410	595	90	634	1595		573	3109	39		17
233	5449	912	31	778	2275	85	1292	2137	78		13
234	4215	1051	63	843	372	12	280	2664	42		13
235	3090	733	31	483	2774	267	784	2377	37		13
236	3138	574	34	747	8712	1666	2361	2360	100		13
237	590	121	2	123	22319	4029	13406	2244	111	137	13
238	61	5		9	28460	2447	21367	1980	53	143	13
239	4207	893	44	751	3258	63	666	2648	103		13
240	3561	574	16	509	39659	5280	10182	2162	136	85	13
241	23	1		3	3654	558	2301	2162	31		13
242	1			1	15390	748	13822	1980	24	75	13
243	10	3		2	5674	2011	1245	2360	68		13
244	2339	636	22	477	3069	73	2107	2458	71	120	13
245	9553	2025	102	1958	4335	685	2919	2384	115		13
246	6065	1384	64	1390	2474	183	908	2676	57		13
247	3197	907	58	727	323	6	234	2858	56		13
248	1			1	306		286	2700	56		13
249	1300	366		371	2		2	2634	24		17
250	7158	1286	57	1278	1950	139	1229	2363	34		13
251	993	234	4	142	12257	742	10487	1324	69	139	13
252	407	89	3	81	18365	1113	15730	1324	90	131	13

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of Lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
1	3	-4	3	1	1	20	31	
1	283	-1	3	1	1		518	200
1	472	+8	9	1	1		1	600
472	1	+8	9	1	1		1	250
2	11	-3	1	1	1	6	32	
2	376	-3	1	1	1	6	40	
2	472	-3	1	1	1	6	35	
3	4	+5	3	1	1	20	33	
3	11	-1	1	1	1		43	200
4	5	-4	3	1	1	20	31	
4	333	+1	1	1	1		43	200
5	6	+5	3	1	1	20	34	
6	7	-5	2	1	1	20	39	
6	471	+8	9	1	1		1	600
471	6	+8	9	1	1		1	250
7	8	-5	2	1	1	20	42	
7	9	-1	2	1	1		23	200
8	16	-1	1	1	1		34	200
8	469	-5	2	1	1	20	38	
9	10	-1	2	1	1		24	200
9	470	-3	2	1	1	6	43	
9	471	-3	2	1	1	6	43	
10	333	-1	2	1	1		41	200
11	333	-3	2	1	1	6	34	
11	376	-1	1	1	1		44	200
12	13	-3	2	1	1	6	56	
12	376	-3	1	1	1	6	14	
13	14	-3	1	1	1	6	34	
13	19	-1	1	1	1		40	200
13	333	-3	1	1	1	6	43	
14	257	-1	2	1	1		41	200
14	470	-3	1	1	1	6	32	
15	16	-3	1	1	1	6	35	
15	470	+8	9	1	1		1	600
16	468	+3	1	1	1	10	45	
16	508	+8	9	1	1		1	600
17	20	-3	2	1	1	6	66	
17	320	-3	2	1	1	6	7	
18	250	+1	1	1	1		13	200
18	255	+5	2	1	1	45	23	
18	256	+5	2	1	1	60	42	
19	20	-1	1	1	1		36	200
19	257	-1	1	1	1		33	200
20	24	-3	1	1	1	4	33	
20	382	-1	1	1	1		37	200
20	473	+8	9	1	1		1	850

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
473	20	+8	9	1	1		1	990
21	257	-1	1	1	1		32	200
21	470	-3	1	1	1	6	40	
21	476	-3	1	1	1	6	38	
22	477	-3	1	1	1	4	37	
22	508	-3	1	1	1	4	57	
23	24	-3	1	1	1	4	33	
23	25	-3	1	1	1	3	21	
23	26	-1	1	1	1		41	200
23	258	-2	2	1	1	7	18	
23	476	+8	9	1	1		1	600
476	23	+8	9	1	1		1	470
24	26	+3	1	1	1	4	23	
24	257	-1	2	1	1		39	200
25	265	-1	1	1	1		19	200
26	27	-1	1	1	1		32	200
26	382	-3	1	1	1	4	35	
26	474	+8	9	1	1		1	850
474	26	+8	9	1	1		1	700
27	29	-1	1	1	1		35	200
28	29	-3	2	1	1	2	34	
28	35	-1	1	1	1		50	200
28	475	-3	2	1	1	4	41	
29	30	-3	1	1	1	2	33	
29	34	-1	1	1	1		42	200
30	382	-6	1	1	1		63	200
31	382	-1	1	1	1		45	200
31	383	-1	1	1	1		33	200
32	303	-3	1	1	1	4	19	
32	382	-3	1	1	1	4	45	
33	227	+4	2	1	1	27	7	
33	435	+4	2	1	1	27	10	
33	442	+8	9	1	1		1	220
442	33	+8	9	1	1		1	210
34	35	-1	1	1	1		32	200
34	317	-1	1	1	1		97	200
34	533	-6	2	1	1		65	200
35	37	-1	1	1	1		65	200
35	350	-1	1	1	1		40	200
36	350	-3	1	1	1	2	35	
36	485	-3	1	1	1	2	18	
37	38	-3	2	1	1	3	34	
37	341	-3	2	1	1	3	34	
38	349	-3	2	1	1	3	61	
38	533	+8	9	1	1		1	990
39	108	-4	2	1	1	45	26	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
39	230	-4	2	1	1	45	21	
39	400	+8	9	1	1		1	143
400	39	+8	9	1	1		1	175
40	230	+4	3	1	1	75	27	
40	252	+4	4	1	1	75	14	
40	418	+8	9	1	1		1	250
418	40	+8	9	1	1		1	143
41	286	-1	1	1	1		518	200
41	298	-6	2	1	1		106	200
41	349	-3	2	1	1	3	36	
41	381	-6	2	1	1		47	200
42	46	-3	1	1	1	1	101	
42	487	-3	1	1	1	1	17	
42	498	+8	9	1	1		1	850
498	42	+8	9	1	1		1	990
43	44	-1	1	1	1		70	200
43	298	-1	1	1	1		41	200
43	349	-1	2	1	1		82	200
44	46	-6	1	1	1		89	200
44	354	-6	2	1	1		21	200
45	46	-6	1	1	1		110	200
45	287	-1	2	1	1		518	200
45	288	-1	1	1	1		518	200
45	298	-6	1	1	1		105	200
47	233	+4	5	1	1	70	7	
47	434	+4	5	1	1	75	10	
47	443	+8	9	1	1		1	220
443	47	+8	9	1	1		1	143
48	49	-3	1	1	1	4	31	
48	289	-1	3	1	1		518	200
48	311	-7	2	2	1		10	200
48	498	-3	1	1	1	4	48	
49	50	-3	1	1	1	4	70	
49	494	+8	9	1	1		1	850
50	123	-3	1	1	1	4	66	
50	505	+8	9	1	1		1	600
505	50	+8	9	1	1		1	850
51	52	-1	2	1	1		58	200
51	56	-2	2	1	1	16	28	
51	364	-3	1	1	1	16	47	
52	53	-1	1	1	1		70	200
52	57	-3	1	1	1	3	23	
52	310	-3	1	1	1	3	31	
53	58	-3	1	1	1	6	22	
53	386	-3	1	1	1	6	29	
54	345	-3	1	1	1	4	25	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
54	392	+3	1	1	1	4	25	
55	340	-1	2	1	1		38	200
55	384	+3	2	1	1	12	35	
55	541	+3	2	1	1	18	29	
56	57	-1	1	1	1		34	200
56	63	+3	2	1	1	15	52	
56	486	+3	1	1	1	2	21	
57	58	-1	1	1	1		70	200
57	63	+1	1	1	1		41	200
57	69	-3	1	1	1	3	55	
58	232	-3	1	1	1	6	40	
58	392	-1	1	1	1		66	200
59	390	+3	1	1	1	4	19	
59	392	+3	1	1	1	4	21	
60	391	-1	2	1	1		19	200
60	393	-1	2	1	1		22	200
61	70	+3	2	1	1	30	20	
61	541	+3	2	1	1	30	21	
62	240	-4	4	1	1	60	21	
62	256	-4	2	1	1	60	26	
62	399	+8	9	1	1		1	143
399	62	+8	9	1	1		1	138
63	68	+3	2	1	1	15	34	
63	87	-1	1	1	1		25	200
64	69	-3	1	1	1	3	38	
64	493	-3	1	1	1	6	41	
64	504	+8	9	1	1		1	600
64	519	-3	2	1	1	9	35	
65	66	+5	2	1	1	15	32	
65	234	+1	2	1	1		37	200
65	389	-1	1	1	1		27	200
65	519	+8	9	1	1		1	700
519	65	+8	9	1	1		1	211
66	67	-4	2	1	1	15	33	
66	73	-1	2	1	1		38	200
66	74	+1	1	1	1		46	200
66	530	+8	9	1	1		1	850
530	66	+8	9	1	1		1	211
67	74	-5	5	1	1	15	31	
67	391	-1	2	1	1		25	200
67	531	+8	9	1	1		1	200
68	493	+8	9	1	1		1	600
68	502	+3	2	1	1	15	52	
70	135	-1	2	1	1		47	200
70	139	+3	2	1	1	36	25	
70	391	-3	2	1	1	6	35	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
71	77	-3	1	1	1	6	34	
71	87	-3	1	1	1	6	32	
72	501	+8	9	1	1		1	300
501	72	+8	9	1	1		1	600
72	502	+8	9	1	1		1	250
502	72	+8	9	1	1		1	600
72	504	-3	2	1	1	6	30	
73	74	+5	2	1	1	15	32	
73	80	-1	2	1	1		28	200
73	234	-5	2	1	1	15	32	
74	81	-5	5	1	1	30	35	
74	529	+8	9	1	1		1	267
529	74	+8	9	1	1		1	300
75	139	-3	2	1	1	24	28	
75	143	-1	1	1	1		22	200
75	407	-3	2	1	1	24	40	
76	265	-3	1	1	1	6	54	
76	482	+3	2	1	1	6	20	
76	483	+8	9	1	1		1	998
483	76	+8	9	1	1		1	475
77	387	+2	1	1	1	6	6	
77	484	+8	9	1	1		1	998
484	77	+8	9	1	1		1	600
78	308	+5	2	1	1	26	11	
78	496	-3	2	1	1	15	26	
78	497	+8	9	1	1		1	400
497	78	+8	9	1	1		1	266
78	502	-3	3	1	1	21	35	
79	80	+5	3	1	1	50	32	
79	308	-4	3	1	1	20	24	
79	518	+8	9	1	1		1	200
518	79	+8	9	1	1		1	250
80	81	+5	3	1	1	50	29	
80	84	+1	2	1	1		18	200
81	82	-4	3	1	1	65	39	
81	528	+8	9	1	1		1	162
528	81	+8	9	1	1		1	250
82	351	+5	3	1	1	65	19	
82	407	+8	9	1	1		1	260
407	82	+8	9	1	1		1	250
82	408	+8	9	1	1		1	270
408	82	+8	9	1	1		1	250
82	409	+8	9	1	1		1	143
409	82	+8	9	1	1		1	250
83	84	-5	2	1	1	27	27	
83	499	-5	2	1	1	27	38	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
83	517	+8	9	1	1		1	200
517	83	+8	9	1	1		1	207
84	85	-5	2	1	1	27	29	
84	239	+1	3	1	1		18	200
85	89	+5	5	1	1	75	17	
85	526	+8	9	1	1		1	400
526	85	+8	9	1	1		1	179
85	528	+3	2	1	1	48	20	
86	277	+1	2	1	1		14	200
86	406	+8	9	1	1		1	143
406	86	+8	9	1	1		1	400
86	526	+3	2	1	1	10	40	
87	493	-3	1	1	1	6	27	
88	489	+3	2	1	1	20	45	
88	495	+8	9	1	1		1	300
495	88	+8	9	1	1		1	250
88	506	+3	2	1	1	20	15	
89	95	-4	5	1	1	75	30	
89	524	+8	9	1	1		1	183
524	89	+8	9	1	1		1	179
89	525	+8	9	1	1		1	250
525	89	+8	9	1	1		1	179
90	387	+3	2	1	1	6	27	
90	480	-3	2	1	1	26	33	
90	481	+8	9	1	1		1	250
481	90	+8	9	1	1		1	600
91	97	-3	2	1	1	10	26	
91	157	-3	1	1	1	10	34	
91	488	+8	9	1	1		1	225
488	91	+8	9	1	1		1	400
92	161	+1	2	1	1		21	200
92	488	+5	3	1	1	24	45	
92	495	-1	4	1	1		34	200
92	511	-5	3	1	1	24	20	
93	155	-3	3	1	1	30	32	
93	513	-2	4	1	1	30	30	
93	515	+8	9	1	1		1	225
515	93	+8	9	1	1		1	200
94	100	-1	3	1	1		28	200
94	239	+1	3	1	1		31	200
94	515	-5	2	1	1	24	20	
94	523	+5	2	1	1	24	26	
95	261	+5	5	1	1	75	13	
95	523	+8	9	1	1		1	225
523	95	+8	9	1	1		1	179
96	216	+5	3	1	1	24	20	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
96	404	+8	9	1	1		1	143
404	96	+8	9	1	1		1	220
96	523	-4	2	1	1	24	39	
97	478	-3	2	1	1	10	31	
98	231	+5	2	1	1	85	9	
98	509	+8	9	1	1		1	165
509	98	+8	9	1	1		1	175
98	510	+8	9	1	1		1	185
98	514	-5	2	1	1	80	34	
99	100	+5	2	1	1	40	22	
99	105	-4	2	1	1	40	23	
99	514	+8	9	1	1		1	10
100	105		3	1	1		10	200
100	522	+5	2	1	1	40	26	
101	218	+1	2	1	2		20	34
101	222	+1	2	1	2		14	34
101	437	+8	9	1	1		1	280
102	220	-4	3	1	1	40	21	
102	402	+8	9	1	1		1	143
402	102	+8	9	1	1		1	185
102	522	+5	2	1	1	40	41	
103	255	+5	2	1	1	45	30	
103	507	+8	9	1	1		1	175
507	103	+8	9	1	1		1	164
103	509	+5	3	1	1	45	55	
104	255		3	1	1		12	200
104	512	+8	9	1	1		1	175
512	104	+8	9	1	1		1	200
104	513	+3	3	1	1	30	34	
105	106	+5	2	1	1	40	28	
105	250	+1	3	1	1		27	200
106	107	+5	2	1	1	40	41	
106	521	+8	9	1	1		1	162
521	106	+8	9	1	1		1	175
107	228	+4	2	1	1	40	21	
107	401	+8	9	1	1		1	143
108	314	-4	2	1	1	93	15	
108	520	-2	3	1	1	48	12	
109	110	+6	3	1	1		72	200
109	316	+6	2	1	1		27	
316	109	+6	4	1	1		27	
109	520	+1	1	1	1		29	200
110	255	+1	3	1	1		17	
110	306	+6	3	1	1		54	200
306	110	+6	1	1	1		54	200
111	114	-6	1	1	1		75	200

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
111	115	-1	1	1	1		31	200
111	122	-6	1	1	1		67	200
112	114	-3	2	1	1	24	36	
112	291	-1	5	1	1		518	200
113	240	+4	4	1	1	60	28	
113	312	+4	4	1	1	60	12	
113	417	+8	9	1	1		1	250
417	113	+8	9	1	1		1	146
114	116	-3	2	1	1	24	40	
114	117	-6	1	1	1		101	200
115	121	-1	1	1	1		38	200
116	119	-3	2	1	1	24	30	
117	118	-3	1	1	1	3	32	
118	119	-6	1	1	1		63	200
118	274	-6	1	1	1		137	200
118	374	-3	1	1	1	3	13	
119	120	-6	1	1	1		33	200
119	372	-3	2	1	1	24	32	
120	121	-6	1	1	1		41	200
121	375	-3	1	1	1	6	40	
121	385	-3	1	1	1	6	48	
122	385	-6	1	1	1		70	200
122	527	+8	9	1	1		1	10
123	124	+3	1	1	1	4	24	
123	503	+8	9	1	1		1	850
124	125	-3	1	1	1	4	45	
124	385	-6	1	1	1		68	200
125	271	-3	1	1	1	4	34	
125	558	+8	9	1	1	1	1	600
558	125	+8	9	1	1	1	1	750
126	338	-3	1	1	1	4	14	
126	375	-1	1	1	1		24	200
127	259	-3	2	1	1	24	25	
127	372	-3	2	1	1	24	11	
128	130	-3	2	1	1	4	38	
128	271	+3	1	1	1	4	16	
128	365	-1	1	1	1		23	200
129	189	+3	1	1	1	14	47	
129	198	+3	2	1	1	16	30	
129	548	+8	9	1	1	1	1	210
548	129	+8	9	1	1	1	1	320
130	154	-1	1	1	1		67	200
130	340	-1	2	1	1		37	200
130	451	+8	9	1	1	1	1	360
451	130	+8	9	1	1	1	1	750
130	535	+8	9	1	1	1	1	175

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of Lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
535	130	+8	9	1	1	1	1	750
131	154	-1	1	1	1		46	200
131	259	-3	1	1	1	3	63	
131	361	-1	1	1	1		67	200
131	374	-3	1	1	1	3	55	
132	133	-2	2	1	1	18	34	
132	318	-3	2	1	1	18	40	
132	570	+8	9	1	1	1	1	290
570	132	+8	9	1	1	1	1	400
133	136	+3	3	1	1	64	30	
133	535	-2	2	1	1	64	36	
133	569	+3	2	1	1	10	16	
134	258	-2	2	1	1	11	59	
134	479	+8	9	1	1		1	225
479	134	+8	9	1	1		1	600
134	480	+8	9	1	1		1	330
480	134	+8	9	1	1		1	600
135	136	-1	1	1	1		29	200
135	140	+3	2	1	1	24	36	
135	570	+3	2	1	1	24	30	
136	137	+1	1	1	1		19	200
136	141	-2	3	1	1	64	36	
137	138	-1	1	1	1		42	200
137	281	+3	2	1	1	16	36	
137	398	-3	2	1	1	16	30	
138	302	-1	1	1	1		22	200
138	560	-3	2	1	1	10	36	
139	531	+3	2	1	1	30	34	
139	568	-2	2	1	1	42	19	
140	357	+1	2	1	1		21	200
140	366	+2	2	1	1	54	6	
140	568	+3	2	1	1	30	28	
141	145	+1	3	1	2		30	34
141	563	+8	9	1	1	1	1	240
141	564	+8	9	1	1	1	1	210
142	148	-2	2	1	1	36	51	
142	281	+3	3	1	1	20	36	
142	560	+8	9	1	1	1	1	290
560	142	+8	9	1	1	1	1	210
143	144	-1	1	1	1		36	200
143	280	-1	1	1	1		36	200
143	351	-3	2	1	1	10	30	
144	366	-1	2	1	1		26	200
144	424	+3	3	1	1	20	45	
144	567	+8	9	1	1	1	1	220
145	150	-1	2	1	2		36	34

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
145	565	+8	9	1	1	1	1	290
565	145	+8	9	1	1	1	1	210
145	566	+8	9	1	1	1	1	340
566	145	+8	9	1	1	1	1	210
146	147	-3	2	1	1	20	35	
146	561	+8	9	1	1	1	1	250
561	146	+8	9	1	1	1	1	290
146	565	-3	2	1	1	20	27	
147	148	-1	2	1	1		36	200
147	152	-1	1	1	1		23	200
147	560	-2	2	1	1	10	29	
148	279	+3	2	1	1	36	18	
149	351	-4	3	1	1	75	26	
149	424	+8	9	1	1		1	250
424	149	+8	9	1	1		1	185
149	425	+5	3	1	1	75	20	
150	377		2	1	2		43	34
150	425	+8	9	1	1		1	185
425	150	+8	9	1	1		1	210
150	426	+8	9	1	1		1	320
426	150	+8	9	1	1		1	210
151	152	+3	1	1	1	10	39	
151	426	-5	3	1	1	30	30	
151	450	+6	2	1	1		43	200
151	561	-4	2	1	1	20	36	
152	189	-1	1	1	1		61	200
152	559	-2	2	1	1	10	39	
153	219	-4	3	1	1	37	22	
153	440	-4	3	1	1	37	11	
153	449	+8	9	1	1		1	280
449	153	+8	9	1	1		1	220
154	156	-1	1	1	1		74	200
154	302	-1	1	1	1		31	200
155	516	+8	9	1	1		1	250
516	155	+8	9	1	1		1	200
155	517	+3	4	1	1	30	18	
156	361	-3	1	1	1	2	70	
156	397	+3	2	1	1	2	36	
157	489	+8	9	1	1		1	250
489	157	+8	9	1	1		1	400
157	490	-3	1	1	1	10	20	
158	159	-1	3	1	1		101	200
158	397	-3	1	1	1	2	62	
158	547	-3	1	1	1	2	94	
159	199	-3	2	1	1	11	76	
159	462	+8	9	1	1		1	850

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
462	159	+8	9	1	1		1	470
160	164	-3	2	1	1	8	58	
160	301	-3	2	1	1	4	22	
160	307	+3	1	1	1	4	41	
161	171	+1	2	1	1		37	200
161	510	-5	2	1	1	40	23	
162	163	-3	1	1	1	4	28	
162	164	+3	1	1	1	4	41	
162	165	-1	1	1	1		65	200
162	307	-1	1	1	1		59	200
163	358	-1	1	1	1		59	200
163	360	-1	1	1	1		27	200
163	373	-1	1	1	1		65	200
164	462	+3	2	1	1	12	66	
165	362	-1	1	1	1		59	200
165	373	-3	1	1	1	4	27	
165	462	-2	1	1	1	4	41	
166	199	+3	1	1	1	10	46	
166	461	+8	9	1	1		1	990
461	166	+8	9	1	1		1	350
167	282	-3	1	1	1	7	72	
167	355	+1	2	1	1		16	200
167	356	-2	2	1	1	16	40	
167	459	+3	2	1	1	36	24	
168	169	-3	1	1	1	9	40	
168	356	-2	1	1	1	9	10	
168	362	-1	1	1	1		56	200
169	268	-3	2	1	1	9	40	
169	276	-1	1	1	1		37	200
169	363	-1	1	1	1		27	200
170	276	-3	3	1	1	7	36	
170	464	+8	9	1	1		1	990
464	170	+8	9	1	1		1	550
171	304	-5	2	1	1	25	37	
171	306		2	1	1		3	200
306	171	-1	2	1	1		3	200
171	507	-5	2	1	1	45	21	
172	173	-3	2	1	1	6	48	
172	367	-3	2	1	1	6	18	
172	368	-1	1	1	1		15	200
173	174	-1	1	1	1		33	200
173	175	-3	2	1	1	6	32	
174	249	-1	1	1	1		63	200
174	370	-3	1	1	1	1	27	
174	465	-3	1	1	1	1	54	
175	371	-3	2	1	1	6	27	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Made Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
175	466	+8	9	1	1		1	990
176	249	-1	1	1	1		29	200
176	299	-6	1	1	1		61	200
176	370	-1	1	1	1		62	200
177	178	-3	2	1	1	6	63	
177	249	-3	1	1	1	6	54	
177	360	-1	1	1	1		53	200
178	275	-3	1	1	1	6	42	
178	368	-1	2	1	1		59	200
178	465	+8	9	1	1		1	990
179	369	-3	1	1	1	1	27	
179	373	-3	1	1	1	1	29	
179	463	+8	9	1	1		1	990
180	309	+5	3	1	1	40	17	
180	491	-5	2	1	1	40	46	
180	496	+8	9	1	1		1	300
496	180	+8	9	1	1		1	175
181	305	-1	1	1	1		28	200
181	367	-3	2	1	1	6	34	
181	464	-3	3	1	1	13	33	
182	183	-6	1	1	1		97	200
182	274	-6	1	1	1		46	200
182	301	-1	1	1	1		45	200
183	184	-6	1	1	1		137	200
183	226	-6	3	1	1		66	200
183	293	-1	2	1	1		518	200
184	188	-6	1	1	1		260	200
184	294	-1	1	1	1		518	200
184	299	-6	1	1	1		65	200
185	186	-3	2	1	1	3	60	
185	371	-3	2	1	1	3	38	
186	187	-3	3	1	1	3	76	
187	188	-6	3	1	1		92	200
188	295	-1	4	1	1		518	200
189	197	-3	2	1	1	16	26	
189	557	-2	2	1	1	30	28	
190	196	-4	3	1	1	24	37	
190	219	+5	3	1	1	37	37	
190	556	+8	9	1	1	1	1	185
556	190	+8	9	1	1	1	1	220
190	557	+8	9	1	1	1	1	380
557	190	+8	9	1	1	1	1	220
191	195	-4	2	1	1	67	33	
191	224	+5	2	1	1	40	40	
191	555	+8	9	1	1	1	1	185
555	191	+8	9	1	1	1	1	195

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
192	194		2	1	1		33	200
192	229	+5	2	1	1	27	40	
192	332	+5	2	1	1	45	13	
192	555	+5	2	1	1	72	11	
193	243	-3	2	1	1	10	78	
243	193	-3	4	1	1	10	78	
193	273	-3	3	1	1	10	11	
193	343	-1	2	1	1		36	200
194	272		2	1	1		35	200
194	553	-2	4	1	1	10	10	
194	554	+3	4	1	1	10	14	
195	206	+5	2	1	1	40	34	
195	552	+8	9	1	1	1	1	210
552	195	+8	9	1	1	1	1	150
195	553	+8	9	1	1	1	1	600
553	195	+8	9	1	1	1	1	195
196	202	-4	3	1	1	24	34	
196	550	+8	9	1	1	1	1	210
550	196	+8	9	1	1	1	1	220
196	551	+8	9	1	1	1	1	210
551	196	+8	9	1	1	1	1	220
197	200	+3	2	1	1	16	34	
197	549	+8	9	1	1	1	1	210
549	197	+8	9	1	1	1	1	400
198	200	+1	1	1	1		28	200
198	546	-3	3	1	1	14	27	
198	547	+8	9	1	1	1	1	998
547	198	+8	9	1	1	1	1	320
199	263	-3	2	1	1	25	25	
200	201	-3	2	1	1	16	25	
200	202	+1	1	1	1		27	200
201	264	-1	2	1	1		30	200
201	545	+8	9	1	1	1	1	600
545	201	+8	9	1	1	1	1	400
202	203	-5	3	1	1	24	24	
202	206	-1	1	1	1		39	200
203	204	+5	3	1	1	24	30	
203	544	+8	9	1	1	1	1	
544	203	+8	9	1	1	1	1	220
204	352	+5	3	1	1	24	30	
204	540	+8	9	1	1		1	360
540	204	+8	9	1	1		1	220
205	352	+5	3	1	1	24	14	
205	459	+8	9	1	1		1	290
459	205	+8	9	1	1		1	230
205	460	+8	9	1	1		1	850

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
460	205	+8	9	1	1		1	230
206	207	-5	2	1	1	40	24	
206	272	+1	2	1	1		13	200
207	208	-1	1	1	1		31	200
207	348	+5	2	1	1	40	36	
207	543	+8	9	1	1	1	1	280
543	207	+8	9	1	1	1	1	185
208	213	+1	2	1	1		19	200
208	346	+5	2	1	1	45	15	
208	348	+1	1	1	1		25	200
208	353	+5	2	1	1	45	32	
209	210	+5	2	1	1	45	18	
209	353	-5	2	1	1	45	20	
210	270	-1	2	1	1		25	200
270	210	-1	2	1	1		25	200
210	355	+1	2	1	1		23	200
355	210	+1	2	1	1		23	200
210	458	+8	9	1	1		1	450
458	210	+8	9	1	1		1	160
211	356		1	1	1		25	200
211	458	+3	2	1	1	15	43	
211	464	-3	2	1	1	15	73	
212	267	+4	2	1	1	40	12	
212	270	-5	2	1	1	40	34	
213	214	-1	2	1	1		42	200
213	267	-5	2	1	1	40	21	
213	347	-5	2	1	1	40	19	
214	343	-1	2	1	1		24	200
214	344		1	1	1		15	200
215	272	-1	2	1	1		11	200
215	339	-5	2	1	1	85	34	
215	342	-1	1	1	1		6	200
215	344	-5	2	1	1	85	24	
216	217	+5	3	1	1	37	26	
216	411	+8	9	1	1		1	190
411	216	+8	9	1	1		1	220
217	334	-4	3	1	1	37	12	
217	422	+8	9	1	1		1	250
422	217	+8	9	1	1		1	220
218	335		2	1	1		10	200
218	377				2		23	34
218	438	+8	9	1	1		1	220
438	218	+8	9	1	1		1	210
219	457	+8	9	1	1		1	340
457	219	+8	9	1	1		1	220
220	221	-4	3	1	1	40	27	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
220	413	+8	9	1	1		1	190
413	220	+8	9	1	1		1	185
221	313	+4	4	1	1	40	12	
221	420	+8	9	1	1		1	250
420	221	+8	9	1	1		1	185
222	359		2	1	2		18	34
222	436	+8	9	1	1		1	185
436	222	+8	9	1	1		1	210
223	224	-4	3	1	1	40	24	
223	315	+4	3	1	1	40	7	
223	448	+8	9	1	1		1	280
448	223	+8	9	1	1		1	185
224	456	+8	9	1	1		1	340
456	224	+8	9	1	1		1	185
225	228	+4	2	1	1	67	27	
225	251	+4	2	1	1	67	13	
225	419	+8	9	1	1		1	250
419	225	+8	9	1	1		1	210
226	299	-1	1	1	1		135	200
226	358	-1	1	1	1		29	200
226	360	-1	1	1	1		59	200
227	229	-4	2	1	1	27	25	
227	447	+8	9	1	1		1	280
447	227	+8	9	1	1		1	210
228	414	+8	9	1	1		1	190
414	228	+8	9	1	1		1	175
229	455	+8	9	1	1		1	340
455	229	+8	9	1	1		1	210
230	415	+8	9	1	1		1	190
415	230	+8	9	1	1		1	175
231	309	-5	2	1	1	40	34	
231	511	+8	9	1	1		1	225
511	231	+8	9	1	1		1	171
232	389	-1	1	1	1		35	200
232	504	-3	1	1	1	6	26	
233	394	-4	4	1	1	70	24	
233	446	+8	9	1	1		1	280
446	233	+8	9	1	1		1	143
234	501	+5	2	1	1	15	38	
234	518	-1	2	1	1		28	200
235	273	+1	2	1	1		33	200
235	297	+1	2	1	1		40	200
235	332		2	1	1		10	200
236	237	-4	3	1	1	60	25	
236	296	+5	2	1	1	60	28	
236	453	+8	9	1	1		1	340

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of Lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
453	236	+8	9	1	1		1	146
237	337	+4	4	1	1	60	7	
237	445	+8	9	1	1		1	280
445	237	+8	9	1	1		1	146
238	242				2		12	34
238	328		2	1	1		9	200
238	388		2	1	2		12	34
238	433	+8	9	1	1		1	146
433	238	+8	9	1	1		1	210
239	516	+3	2	1	1	20	25	
239	525	+3	3	1	1	20	28	
240	416	+8	9	1	1		1	190
416	240	+8	9	1	1		1	146
241	316	+6	3	1	1		21	200
316	241	-1	1	1	1		21	200
241	323	-2	2	1	1	35	13	
241	325	+6	1	1	1		30	200
325	241	+6	3	1	1		30	200
242	324		2	1	1		11	200
242	326	-4	2	1	1	36	10	
242	328		2	1	1		8	200
242	432	+4	2	1	1	36	9	
243	331	+6	2	1	1		25	200
331	243	+6	4	1	1		25	200
243	452	+8	9	1	1		1	340
452	243	+8	9	1	1		1	600
244	245	+5	3	1	1	36	20	
244	335	-1	2	1	1		10	200
244	427	-5	3	1	1	36	15	
245	246	-4	2	1	1	36	26	
245	277	+1	2	1	1		34	200
245	423	+8	9	1	1		1	250
423	245	+8	9	1	1		1	185
246	262	+5	2	1	1	36	20	
246	410	+8	9	1	1		1	360
410	246	+8	9	1	1		1	185
247	348	+5	2	1	1	40	31	
247	537	+3	2	1	1	10	19	
247	538	+8	9	1	1		1	600
538	247	+8	9	1	1		1	230
247	539	+5	2	1	1	50	16	
248	306	+6	1	1	1		36	200
248	322	+6	3	1	1		15	200
248	478		2	1	1		3	200
250	314	+5	2	1	1	45	27	
250	512	+5	2	1	1	45	22	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of Lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
251	430	+8	9	1	1		1	185
251	435	+4	2	1	1	27	7	
252	431	+8	9	1	1		1	185
252	434	+4	4	1	1	75	7	
253	439	-3	1	1	1	18	23	
253	450	+8	9	1	1		1	280
450	253	+8	9	1	1		1	270
254	274	-6	1	1	1		64	200
254	300	-1	1	1	1		31	200
254	301	-1	1	1	1		52	200
301	254	-1	1	1	1		52	200
256	520	+8	9	1	1		1	162
520	256	+8	9	1	1		1	145
258	475	-3	1	1	1	4	43	
258	477	+8	9	1	1		1	600
477	258	+8	9	1	1		1	470
259	451	-3	2	1	1	27	32	
260	261	+5	2	1	1	27	40	
260	403	+8	9	1	1		1	143
403	260	+8	9	1	1		1	210
260	412	-4	2	1	1	27	21	
261	379	+3	5	1	1	48	15	
262	405	+8	9	1	1		1	143
405	262	+8	9	1	1		1	185
262	524	+5	2	1	1	36	39	
263	264	+3	4	1	1	10	27	
263	278	-3	3	1	1	15	29	
264	540	-3	4	1	1	10	27	
265	474	-3	1	1	1	6	39	
265	475	+8	9	1	1		1	470
266	380	+3	2	1	1	15	26	
266	412	+8	9	1	1		1	190
412	266	+8	9	1	1		1	280
267	536	+8	9	1	1		1	400
536	267	+8	9	1	1		1	175
268	275	-3	1	1	1	6	40	
268	305	-1	1	1	1		27	200
268	363	-1	1	1	1		27	200
268	463	-3	1	1	1	3	59	
269	272		2	1	1		24	200
269	346	+1	2	1	1		18	200
269	542	-4	2	1	1	13	10	
269	543	+5	2	1	1	13	15	
271	534	+8	9	1	1	1	1	750
273	342	+1	2	1	1		35	200
273	554	-3	4	1	1	10	10	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
274	292	-1	3	1	1		518	200
275	305	-1	1	1	1		28	200
275	369	-1	1	1	1		30	200
276	356	-3	2	1	1	7	28	
277	351	-1	1	1	1		32	200
277	410		2	1	1		14	200
278	545	+3	2	1	1	15	27	
278	546	+8	9	1	1	1	1	320
546	278	+8	9	1	1	1	1	600
279	548	+3	2	1	1	26	55	
279	559	+8	9	1	1	1	1	320
559	279	+8	9	1	1	1	1	210
280	357	-3	1	1	1	12	34	
280	568	+8	9	1	1	1	1	200
568	280	+8	9	1	1	1	1	300
281	562	+8	9	1	1	1	1	250
562	281	+8	9	1	1	1	1	240
281	563	+3	3	1	1	36	23	
282	362	-1	1	1	1		27	200
282	461	-2	1	1	1	7	14	
284	376	-1	7	1	1		518	200
285	320	-1	2	1	1		518	200
290	500	+8	9	1	1		1	10
290	527	-1	2	1	1		518	200
296	332	+5	2	1	1	99	14	
296	394	+5	2	1	1	70	25	
297	330		2	1	1		25	200
297	452	+3	3	1	1	10	13	
297	453	+2	3	1	1	10	5	
300	361	-3	1	1	1	2	37	
300	397	-3	1	1	1	2	70	
302	569	-3	1	1	1	10	50	
303	320	-7	3	2	1		60	200
303	383	-7	3	2	1		32	200
304	322	-4	2	1	1	25	15	
304	478	+8	9	1	1		1	400
478	304	+8	9	1	1		1	250
305	368	-1	1	1	1		27	200
307	358	-1	1	1	1		25	200
308	499	+8	9	1	1		1	207
499	308	+8	9	1	1		1	250
309	506	+8	9	1	1		1	250
506	309	+8	9	1	1		1	175
310	311	-7	2	2	1		27	200
310	386	-7	2	2	1		71	200
310	494	-3	1	1	1	3	12	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
311	364	-7	2	2	1		48	200
312	432	+8	9	1	1		1	220
432	312	+8	9	1	1		1	146
312	433	+4	4	1	1	60	7	
313	429	+8	9	1	1		1	185
313	436	+4	4	1	1	40	8	
314	521	+3	5	1	1	48	19	
315	436	+4	3	1	1	40	10	
315	441	+8	9	1	1		1	220
441	315	+8	9	1	1		1	185
316	319	-4	2	1	1	20	16	
317	381	-7	2	2	1		19	200
317	383	-7	3	2	1		65	200
318	393	-1	1	1	1		37	200
318	541	+8	9	1	1	1	1	550
319	323		1	1	1		21	200
319	399	-4	2	1	1	20	12	
320	376	-7	2	2	1		64	200
321	322	+4	3	1	1	25	9	
321	376	-7	2	2	1		212	200
321	468	+8	9	1	1		1	600
468	321	+8	9	1	1		1	250
321	469	+8	9	1	1		1	250
322	480	-1	2	1	1		65	200
323	324		2	1	1		29	200
323	416	+2	4	1	1	35	10	
324	325		2	1	1		14	200
324	417	+2	3	1	1	10	10	
325	326	+6	3	1	1		10	200
326	325	+6	5	1	1		10	200
326	327	+6	3	1	1		7	200
327	326	+6	5	1	1		7	200
327	328		2	1	1		9	200
327	331	+6	4	1	1		16	200
331	327	+6	2	1	1		16	200
328	329		3	1	1		10	200
329	330		3	1	1		6	200
329	444	+2	2	1	1	24	4	
330	331	+3	1	1	1	17	14	
330	445	-2	2	1	1	17	4	
332	339	+5	2	1	1	85	33	
334	427	+8	9	1	1		1	185
427	334	+8	9	1	1		1	220
334	438	-4	2	1	1	37	8	
335	336	-1	1	1	1		16	200
335	377	+1	2	1	1		13	200

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

Node from	Node to	Capacity Code	Number of lanes	Made Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
336	440	+8	9	1	1		1	220
336	441	+3	2	1	1	24	34	
337	433	+4	4	1	1	60	10	
337	444	+8	9	1	1		1	220
444	337	+8	9	1	1		1	146
338	365	-7	2	2	1		24	200
338	384	-7	2	2	1		36	200
338	534	-3	3	1	1	4	12	
339	554	+8	9	1	1	1	1	600
554	339	+8	9	1	1	1	1	150
340	534	-2	3	1	1	4	30	
340	570	+3	4	1	1	24	37	
341	485	+8	9	1	1		1	998
341	486	+8	9	1	1		1	300
342	343	-1	1	1	1		9	200
342	344	+1	2	1	1		26	200
344	347	-5	2	1	1	85	12	
344	542	+8	9	1	1	1	1	280
542	344	+8	9	1	1	1	1	145
345	384	-7	2	2	1		67	200
345	386	-7	2	2	1		66	200
345	503	-3	1	1	1	4	18	
346	347	+5	2	1	1	45	10	
348	540	+1	1	1	1		17	200
349	354	-7	2	2	1		75	200
349	381	-7	2	2	1		60	200
350	483	-3	1	1	1	2	79	
352	539	+8	9	1	1		1	230
539	352	+8	9	1	1		1	220
353	537	+8	9	1	1		1	400
537	353	+8	9	1	1		1	160
354	364	-7	2	2	1		46	200
354	533	-6	2	1	1		45	200
355	356	-1	1	1	1		47	200
355	538	-3	2	1	1	6	38	
357	567	+2	1	1	1	12	8	
359	388		2	1	2		15	34
359	435	+8	9	1	1		1	210
360	463	-3	1	1	1	3	64	
362	363	-1	1	1	1		27	200
363	373	-1	1	1	1		57	200
364	487	+8	9	1	1		1	998
487	364	+8	9	1	1		1	300
365	372	-7	2	2	1		30	200
366	564	-2	2	1	1	54	20	
367	368	-1	2	1	1		10	200

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

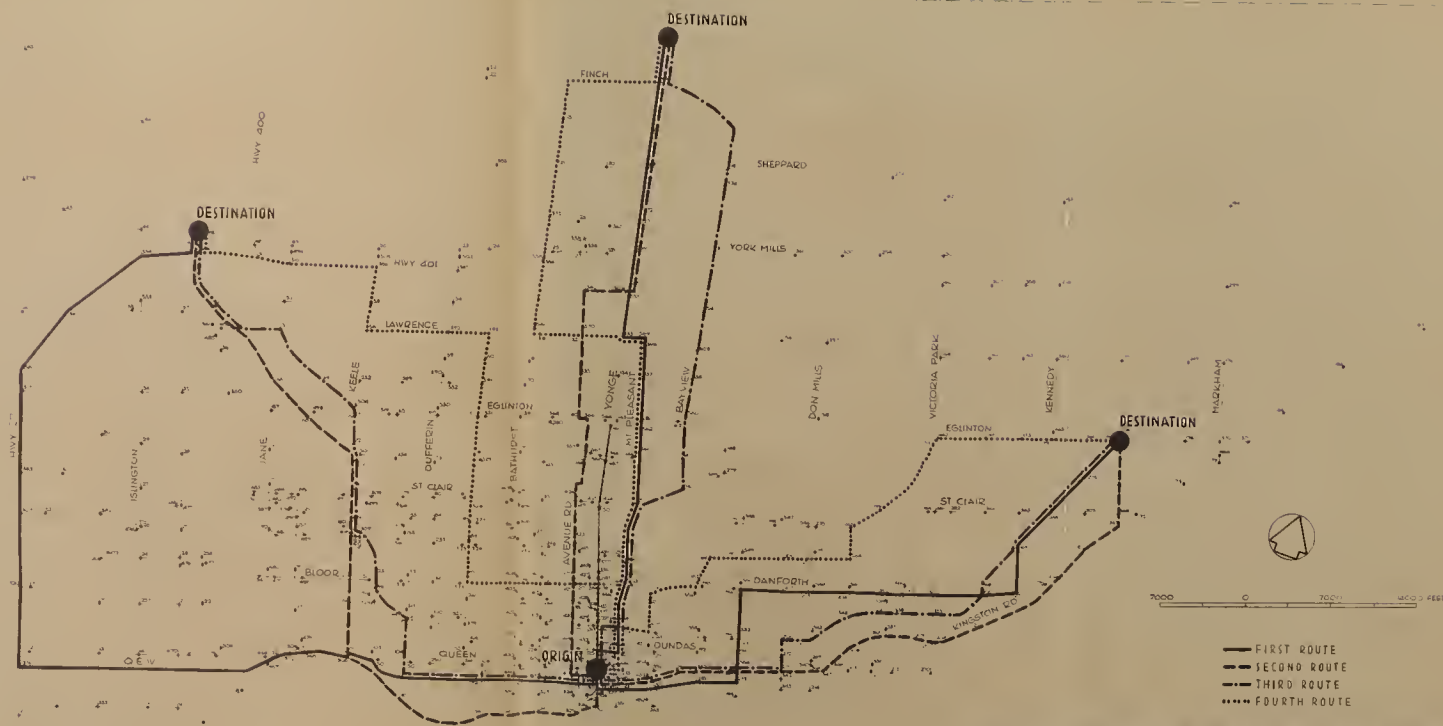
Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
369	465	-3	1	1	1	1	27	
370	466	+3	1	1	1	1	15	
370	467	+3	1	1	1	1	23	
371	467	+8	9	1	1		1	990
372	374	-7	2	2	1		69	200
375	558	-3	1	1	1	12	29	
377	439	+8	9	1	1		1	270
439	377	+8	9	1	1		1	210
378	380	-2	2	1	1	15	13	
378	428	+8	9	1	1		1	185
428	378	+8	9	1	1		1	280
378	437	-2	2	1	1	15	8	
379	521	+3	5	1	1	48	19	
379	522	+8	9	1	1		1	185
522	379	+8	9	1	1		1	160
380	421	+8	9	1	1		1	250
421	380	+8	9	1	1		1	280
384	558	-2	2	1	1	12	4	
386	505	+3	1	1	1	6	15	
387	482	+8	9	1	1		1	850
482	387	+8	9	1	1		1	600
388	434	+8	9	1	1		1	143
434	388	+8	9	1	1		1	210
389	532	-1	1	1	1		31	200
390	530	+3	1	1	1	4	25	
390	532	+8	9	1	1		1	530
532	390	+8	9	1	1		1	850
391	532	-3	2	1	1	6	33	
392	393	-1	1	1	1		31	200
394	454	+8	9	1	1		1	340
454	394	+8	9	1	1		1	143
395	490	+3	1	1	1	12	12	
395	492	+8	9	1	1		1	998
492	395	+8	9	1	1		1	400
395	497	-3	1	1	1	10	44	
396	482	+3	2	1	1	6	25	
396	490	+8	9	1	1		1	400
490	396	+8	9	1	1		1	850
396	491	+8	9	1	1		1	175
491	396	+8	9	1	1		1	850
398	569	+8	9	1	1	1	1	500
569	398	+8	9	1	1	1	1	290
399	400	-4	3	1	1	20	12	
400	401	-4	4	1	1	20	19	
401	402	-4	4	1	1	20	16	
402	403	+5	4	1	1	20	19	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

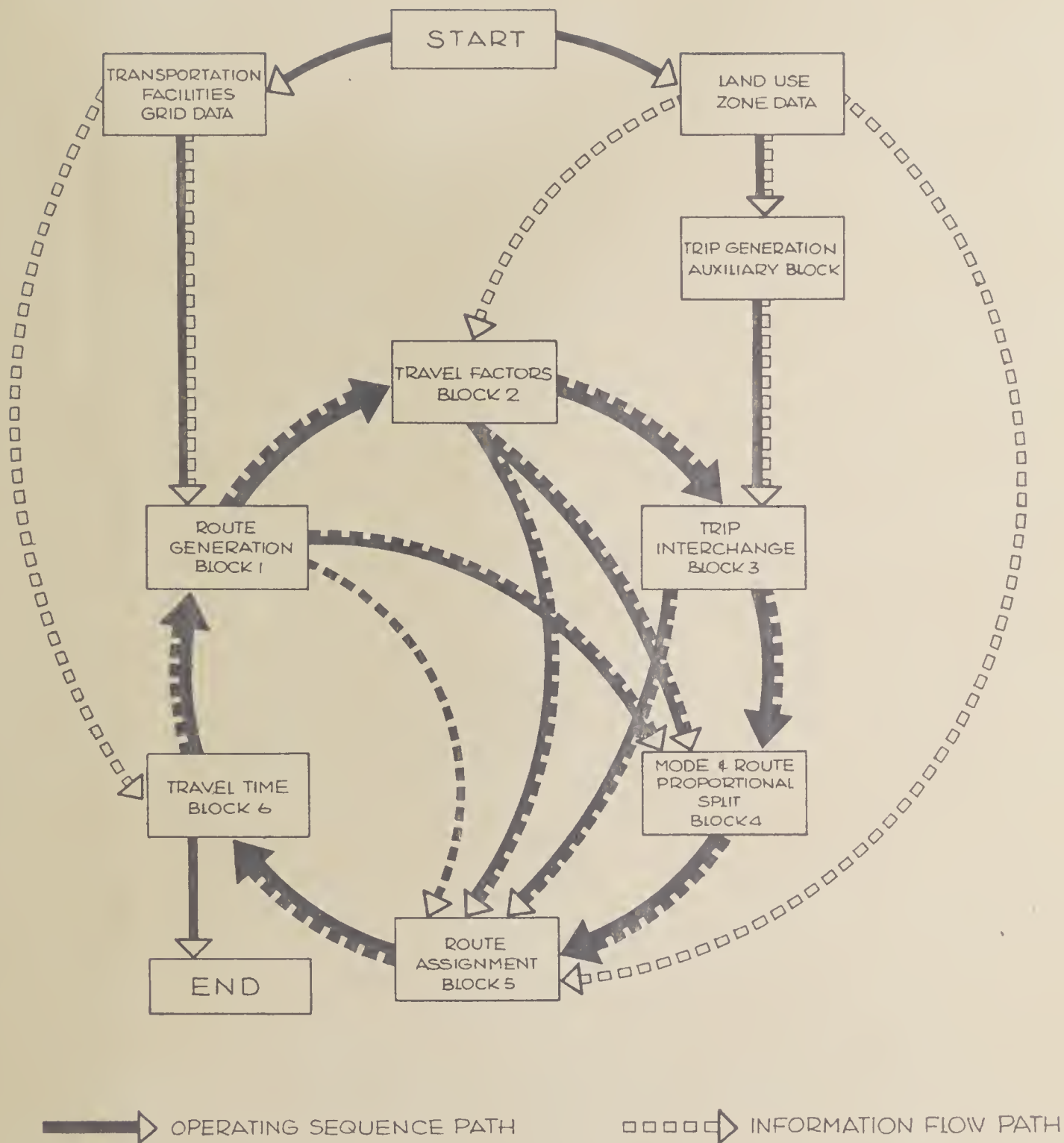
Node from	Node to	Capacity Code	Number of Lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
403	404	+5	4	1	1	20	14	
404	405	+5	2	1	1	20	29	
405	406	+5	4	1	1	20	13	
406	409	+5	2	1	1	20	23	
407	408	+8	9	1	1		1	270
408	407	+8	9	1	1		1	260
407	409	+8	9	1	1		1	143
409	407	+8	9	1	1		1	260
408	409	+8	9	1	1		1	143
409	408	+8	9	1	1		1	270
408	529	-3	2	1	1	18	52	
410	411	-3	6	1	1	20	30	
411	412	+3	6	1	1	20	13	
412	413	+5	4	1	1	47	19	
413	414	-4	5	1	1	27	18	
414	415	+2	3	1	1	35	15	
415	416	+2	4	1	1	35	12	
417	418	+2	4	1	1	10	13	
418	419	+2	4	1	1	10	15	
419	420	-2	4	1	1	10	19	
420	421	-2	3	1	1	10	20	
421	422	-2	3	1	1	20	13	
422	423	+3	3	1	1	20	32	
423	424	-2	4	1	1	20	35	
425	426	+8	9	1	1		1	320
426	425	+8	9	1	1		1	185
427	428	+5	3	1	1	36	17	
428	429	+5	3	1	1	36	16	
429	430	+4	3	1	1	36	18	
430	431	+4	3	1	1	36	15	
431	432	+4	2	1	1	36	12	
438	440	-4	2	1	1	37	10	
441	442	+2	4	1	1	24	20	
442	443	+2	4	1	1	24	13	
443	444	+2	2	1	1	24	12	
445	446	+2	2	1	1	17	12	
446	447	+2	3	1	1	17	13	
447	448	-2	3	1	1	17	20	
448	449	+3	2	1	1	17	37	
449	450	+6	2	1	1	17	24	
451	535	+8	9	1	1	1	1	175
535	451	+8	9	1	1	1	1	360
453	454	-2	4	1	1	12	10	
454	455	+2	4	1	1	12	14	
455	456	-2	4	1	1	12	15	
456	457	+3	3	1	1	12	31	

TABLE 2 — LINK INPUT DATA FOR 1956 TEST RUNS

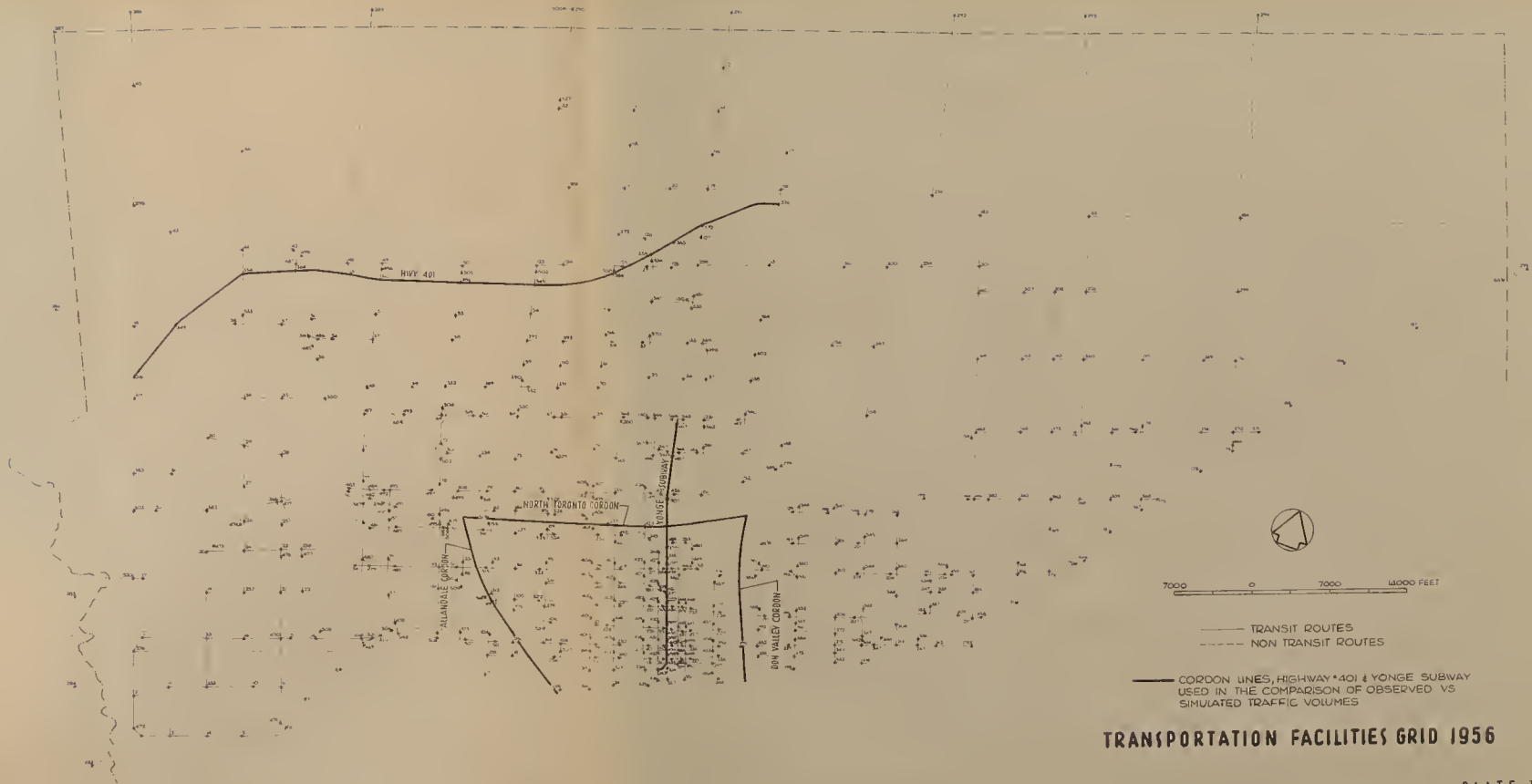
Node from	Node to	Capacity Code	Number of lanes	Mode Code		Number of Transit Vehicles	Length 1 unit = .01894 mi.	Transit Time min/mile
				1 = Arterial 2 = Expressway	1 = Surface Transit 2 = Subway			
460	461	-3	1	1	1	12	66	
461	462	+3	2	1	1	19	60	
468	469	+8	9	1	1		1	250
469	468	+8	9	1	1		1	600
473	474	+3	1	1	1	6	42	
479	480	+8	9	1	1		1	330
480	479	+8	9	1	1		1	225
479	488	-4	3	1	1	24	22	
481	489	+3	3	1	1	20	23	
483	484	+3	1	1	1	2	19	
484	492	+3	1	1	1	2	23	
485	486	+8	9	1	1		1	300
486	485	+8	9	1	1		1	998
490	491	+8	9	1	1		1	175
491	490	+8	9	1	1		1	400
495	496	+2	2	1	1	15	7	
501	502	+8	9	1	1		1	250
502	501	+8	9	1	1		1	300
506	516	+3	2	1	1	20	28	
507	512	+5	2	1	1	45	26	
509	510	+8	9	1	1		1	185
510	509	+8	9	1	1		1	165
511	515	-5	2	1	1	24	27	
513	514	+8	9	1	1		1	179
514	513	+8	9	1	1		1	200
517	518	+3	2	1	1	30	18	
524	525	+8	9	1	1		1	250
525	524	+8	9	1	1		1	183
536	537	-3	2	1	1	10	32	
543	544	+5	2	1	1	13	39	
544	545	-2	2	1	1	23	27	
548	549	+3	2	1	1	26	28	
549	550	-3	4	1	1	26	26	
550	551	+8	9	1	1	1	1	210
551	552	-5	4	1	1	27	39	
552	553	+8	9	1	1	1	1	600
553	552	+8	9	1	1	1	1	210
555	556	-5	2	1	1	45	42	
556	557	+8	9	1	1	1	1	380
567	566	+3	1	1	1	22	18	
561	562	+5	2	1	1	20	29	
563	564	+8	9	1	1	1	1	165
564	563	+8	9	1	1	1	1	170
565	566	+8	9	1	1	1	1	340
566	565	+8	9	1	1	1	1	290
566	567	+3	1	1	1	22	18	



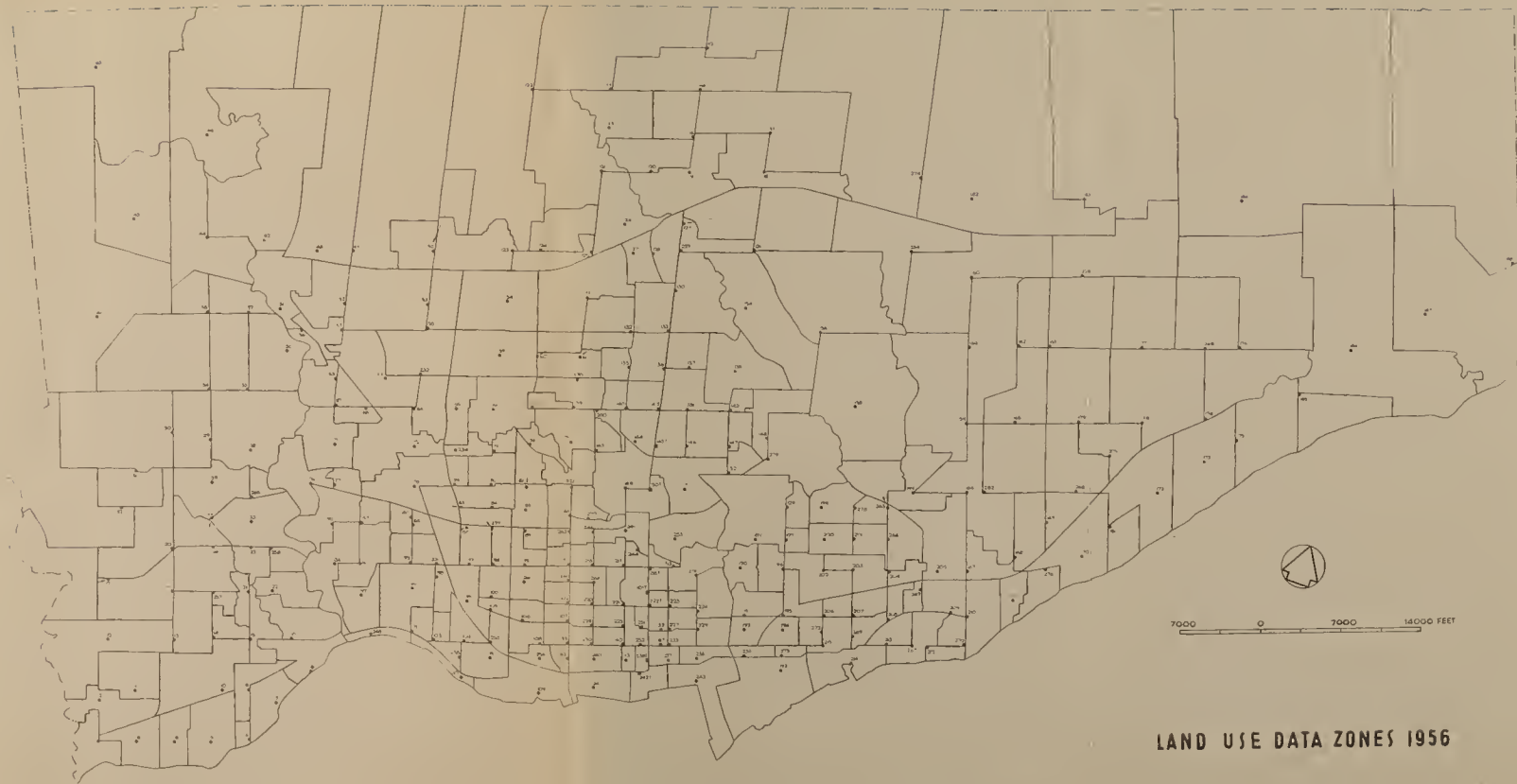
ROUTES BETWEEN AN ORIGIN AND THREE DESTINATIONS 1956
(AS CONSTRUCTED BY ROUTE GENERATION BLOCK)



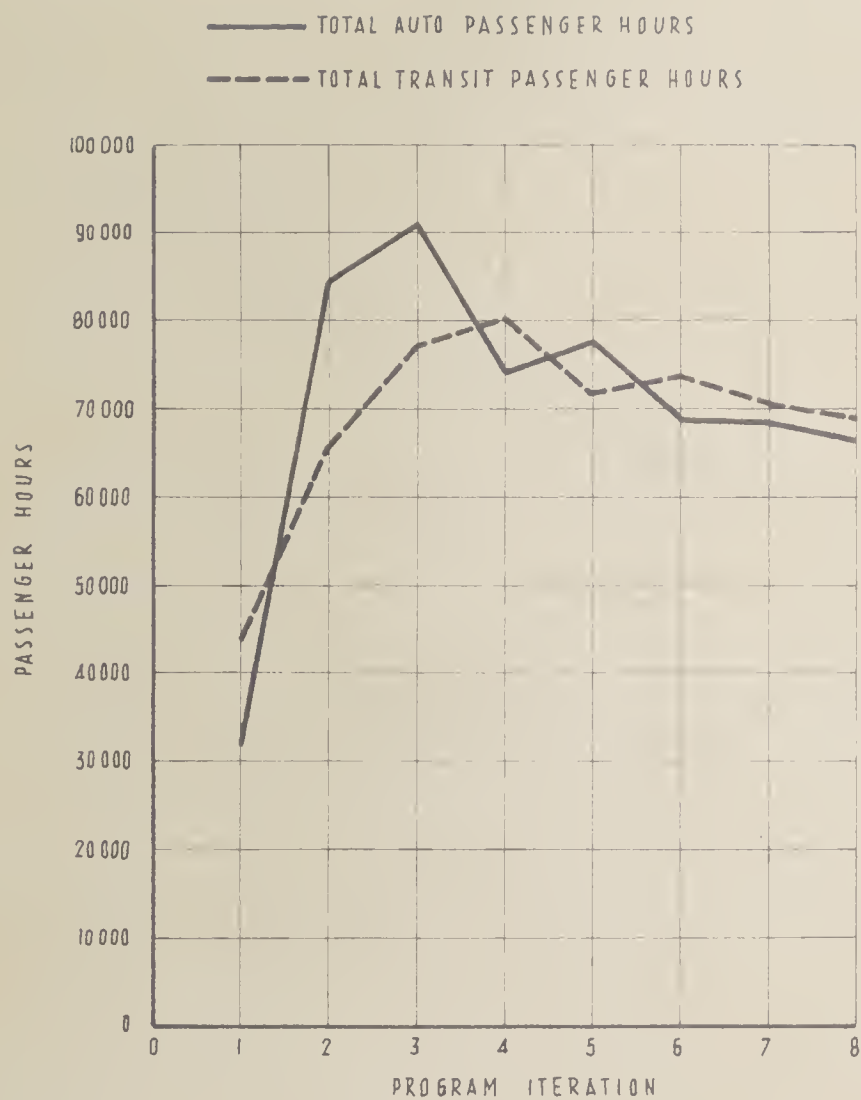
FLOW OF INFORMATION AND OPERATING SEQUENCE
OF MAIN PROGRAM BLOCKS OF THE
TRAFFIC PREDICTION MODEL



TRANSPORTATION FACILITIES GRID 1956

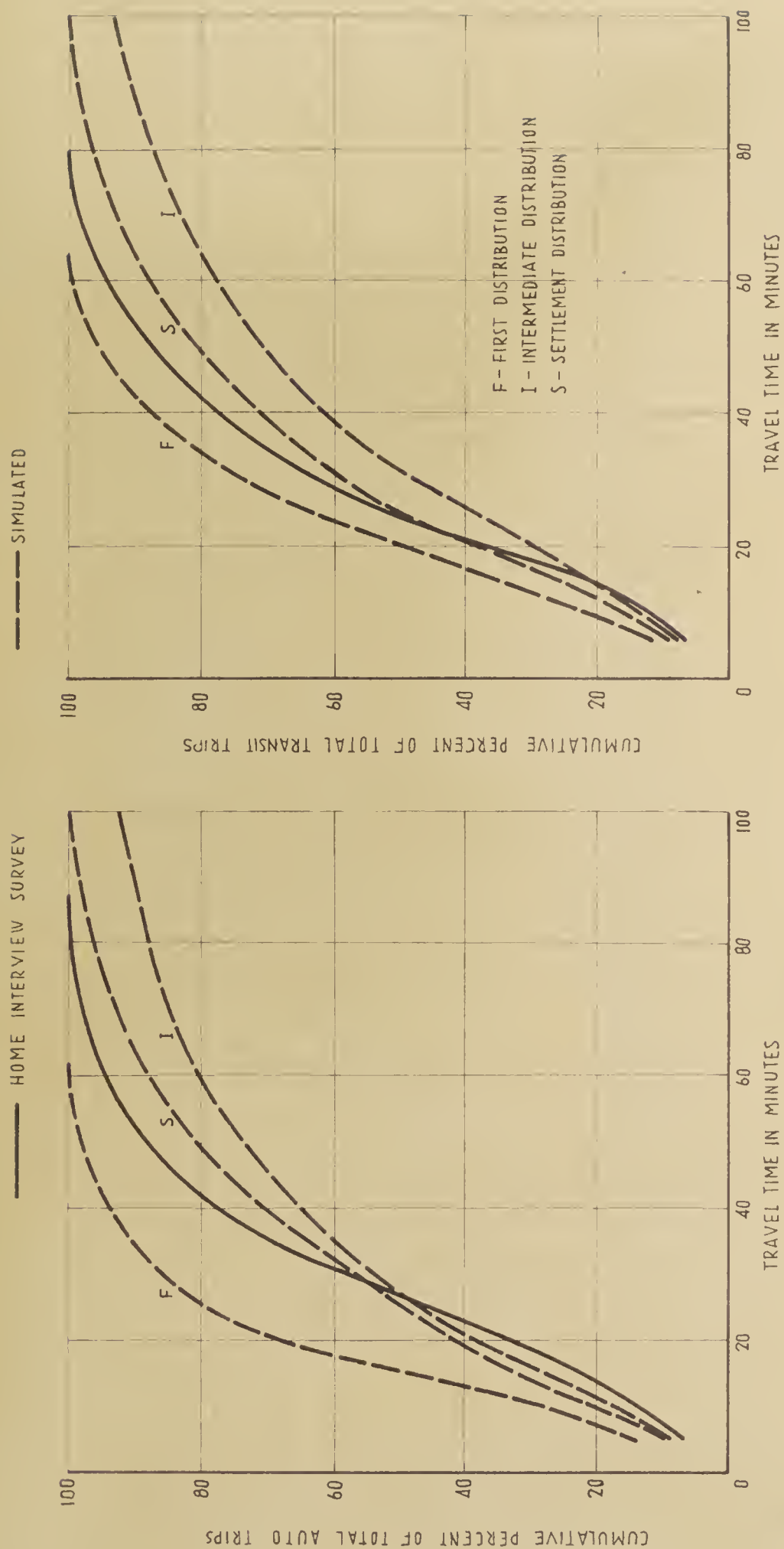


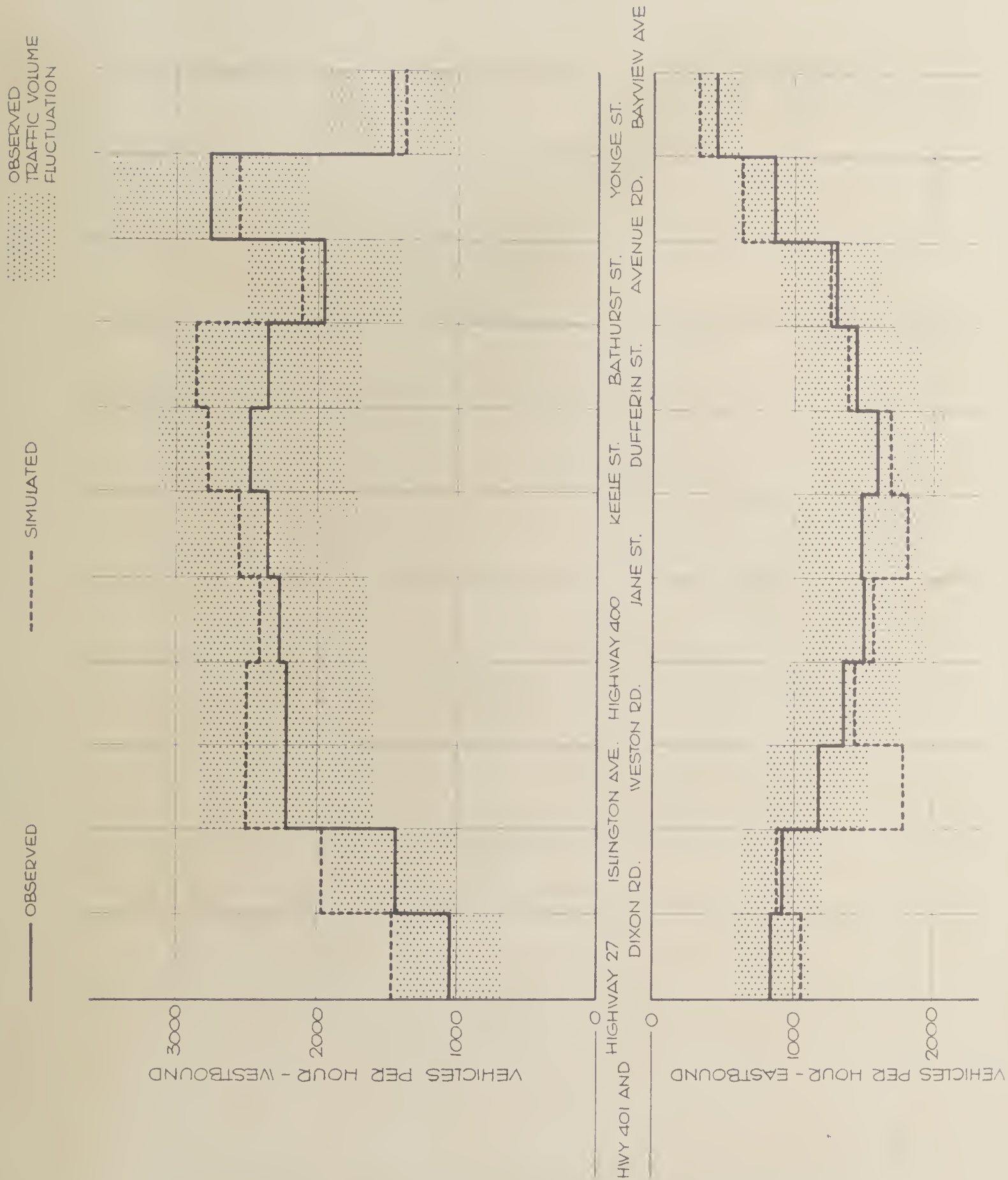
LAND USE DATA ZONES 1956



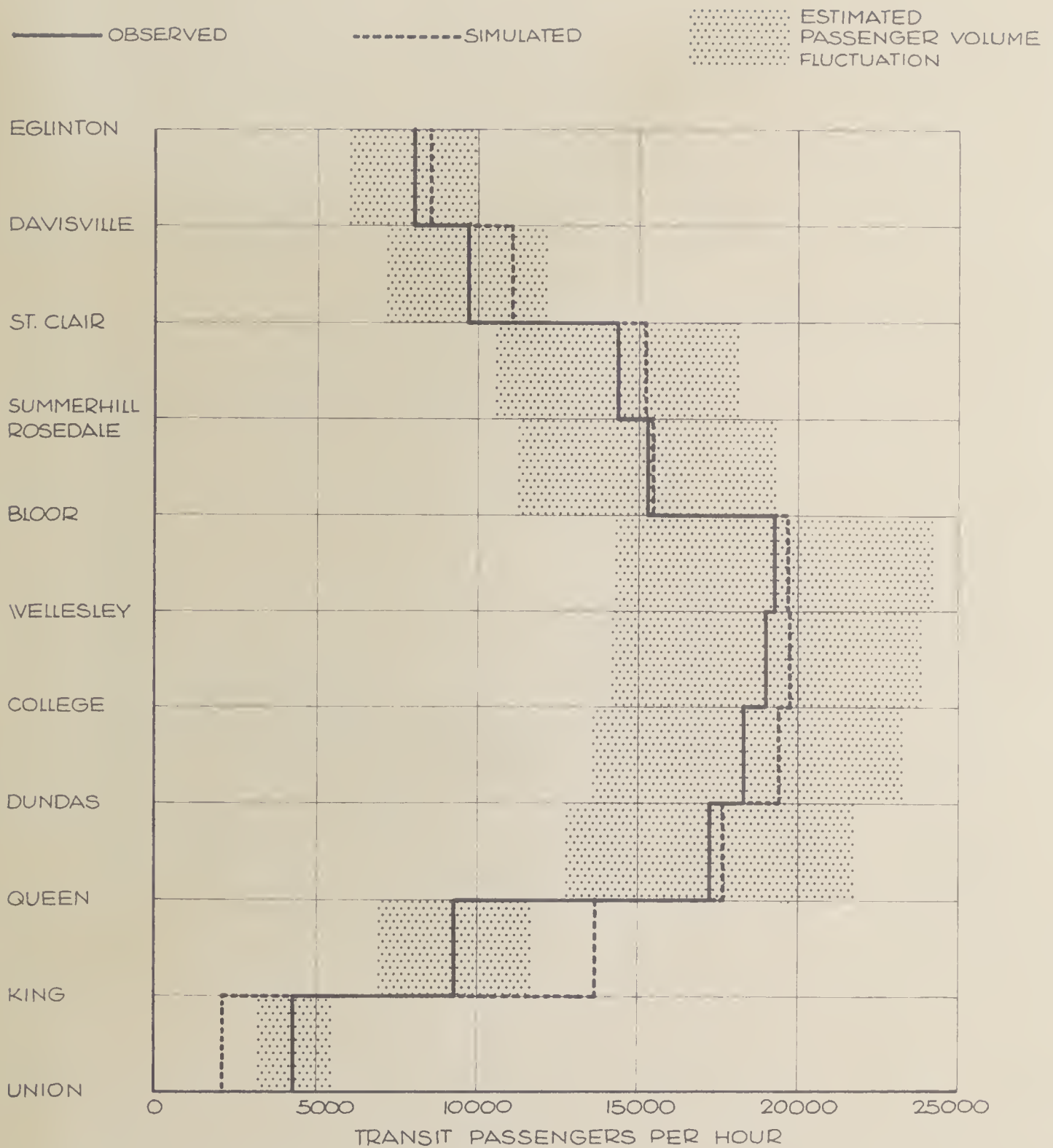
AUTO AND TRANSIT PASSENGER TRAVEL TIME CHART

TRIP DISTRIBUTION — TRAVEL TIME COMPARISON

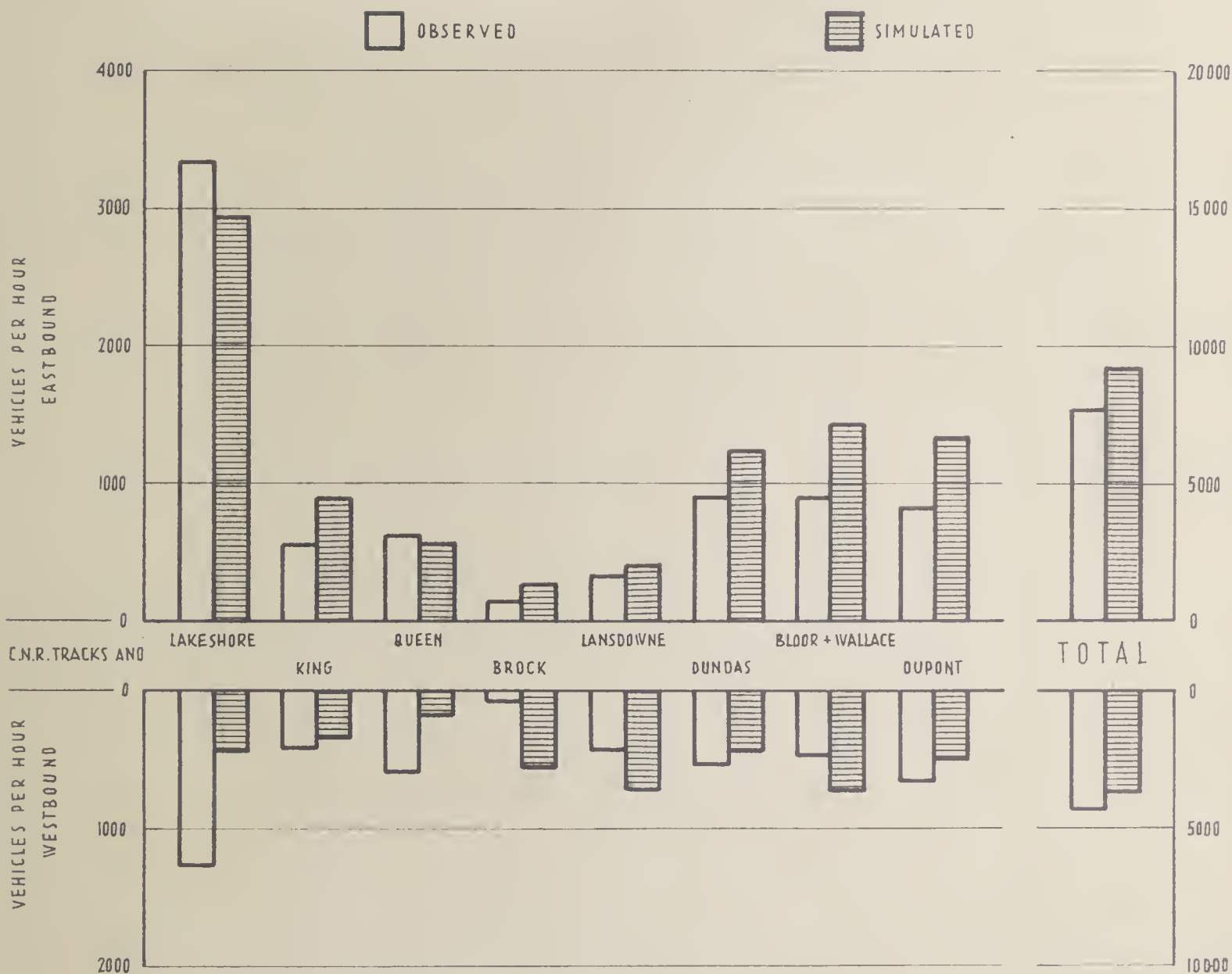




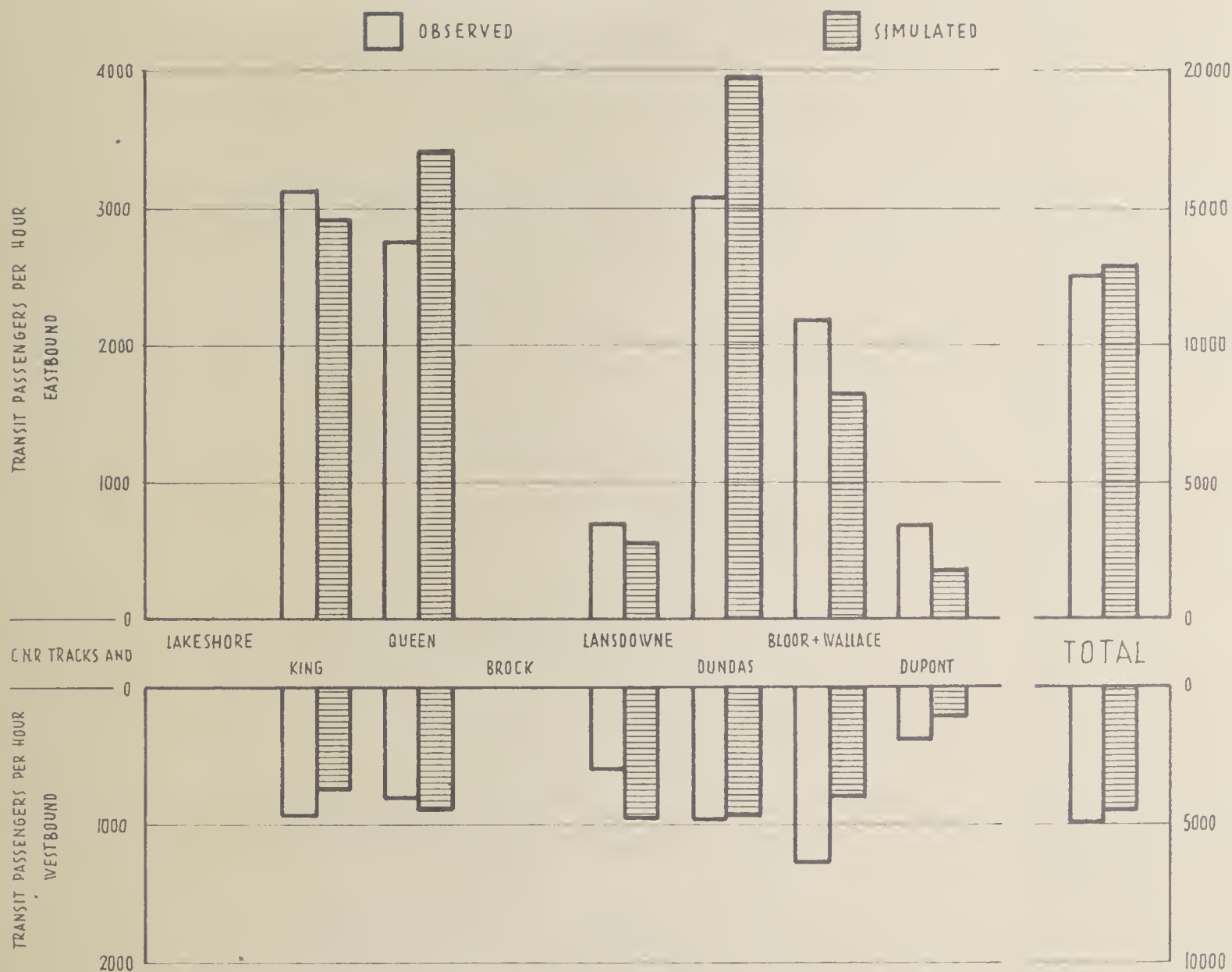
AUTOS AND TRUCKS ON HIGHWAY 401 DURING RUSH HOUR IN 1956



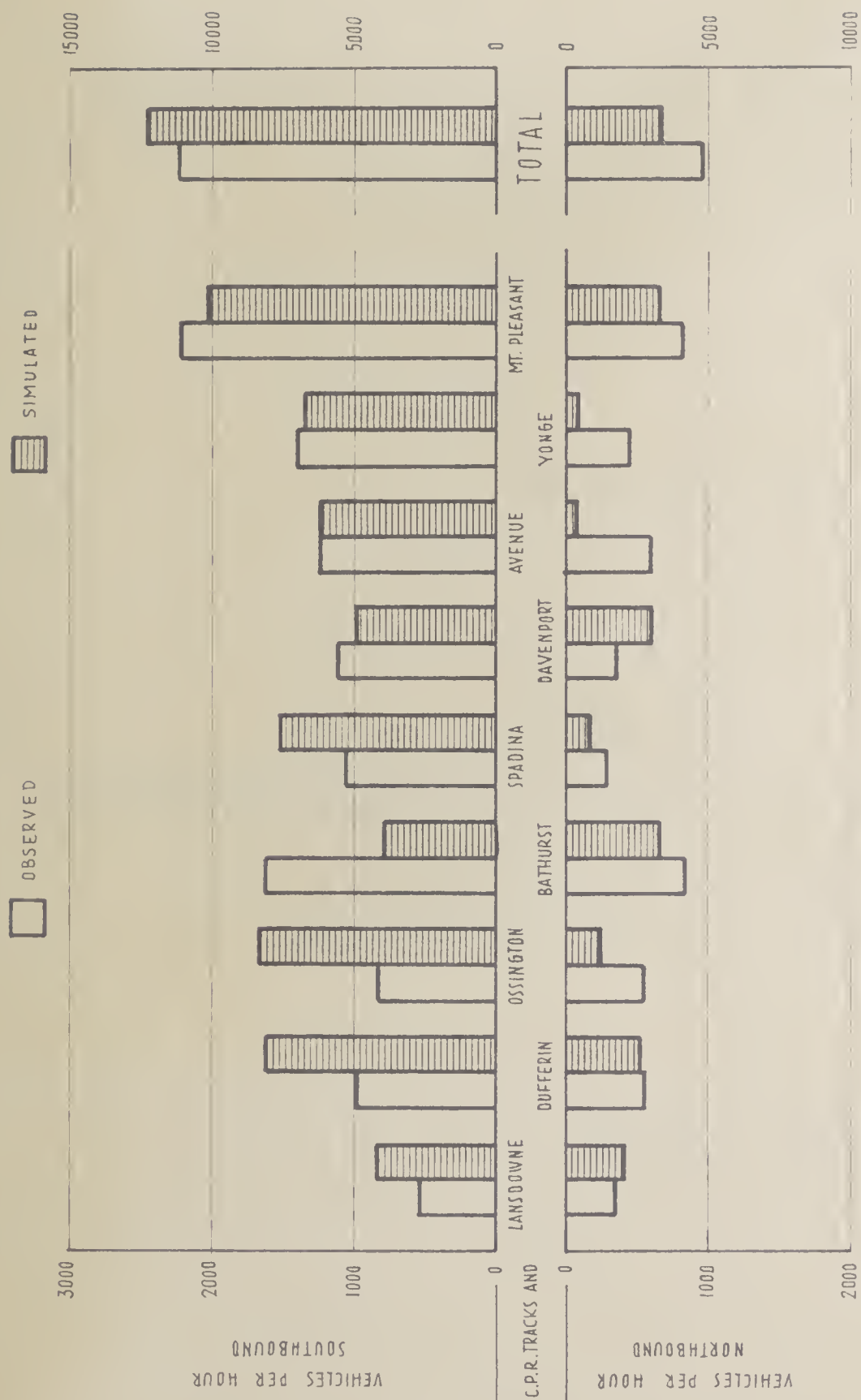
**OBSERVED VS. SIMULATED PASSENGERS
ON YONGE ST. SUBWAY BOTH WAYS
FOR A.M. RUSH HOUR IN 1956**



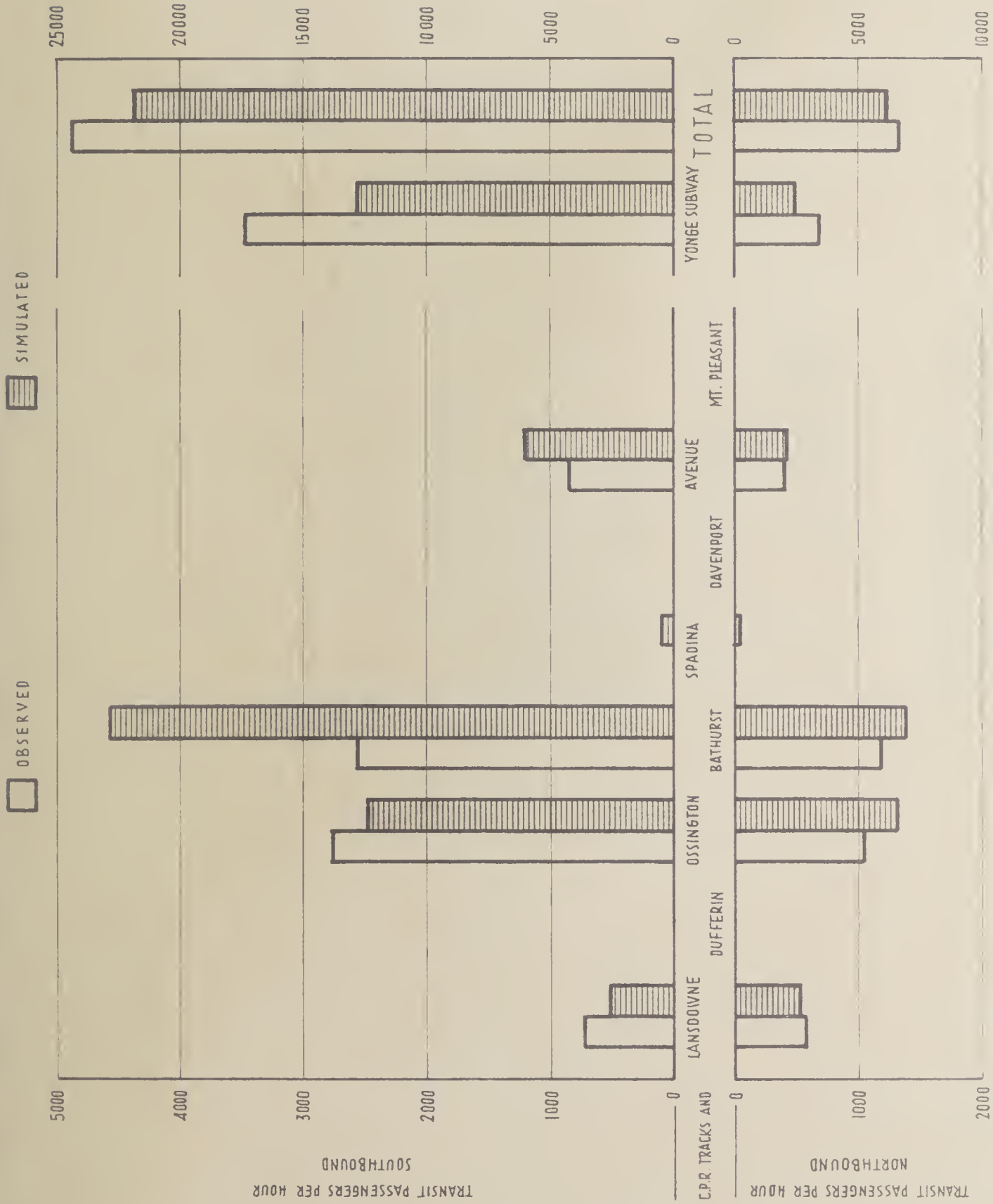
AUTOS AND TRUCKS CROSSING ALLANDALE CORDON DURING A.M. RUSH HOUR IN 1956



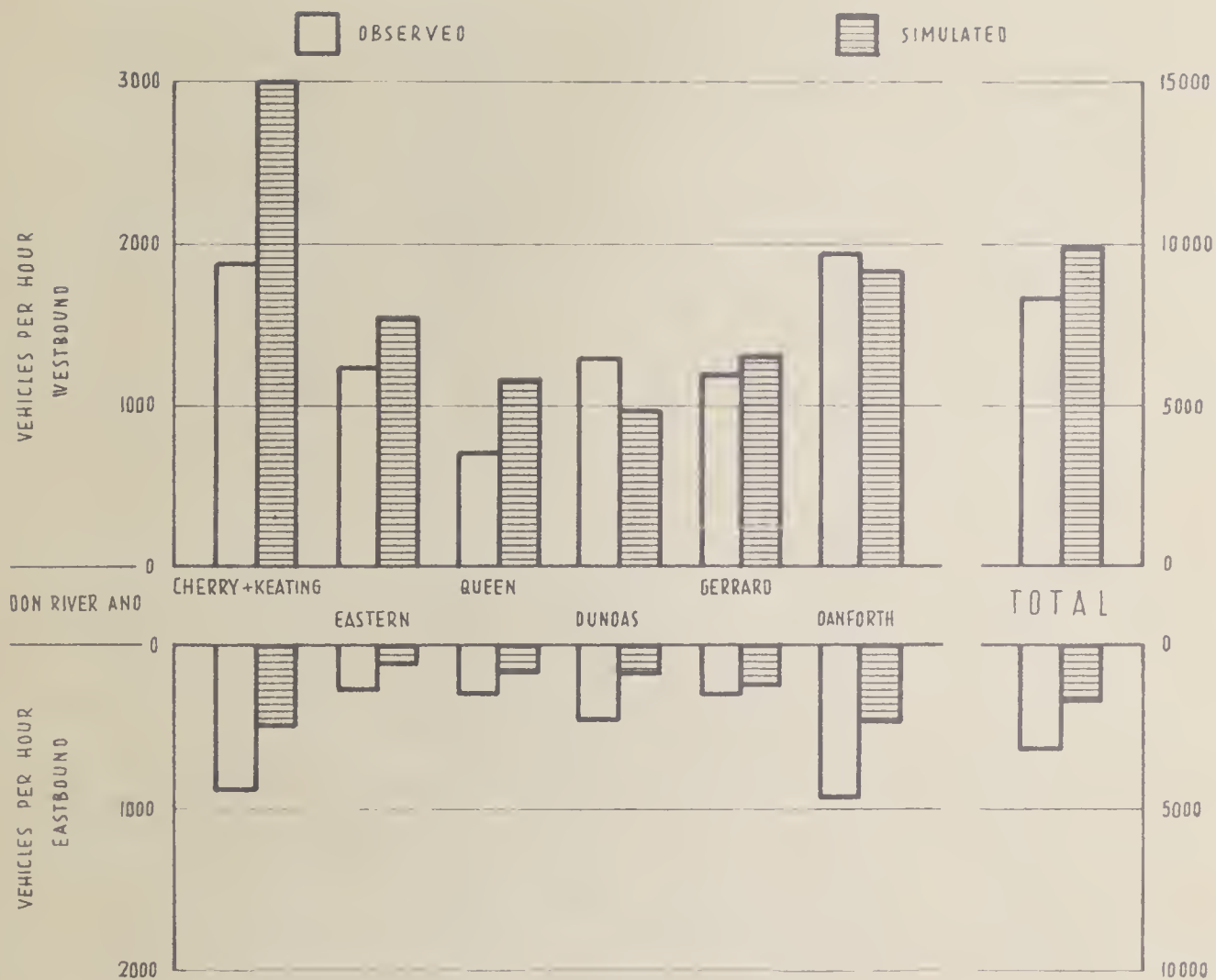
TRANSIT PASSENGERS CROSSING ALLANDALE CORDON DURING A.M. RUSH HOUR IN 1956



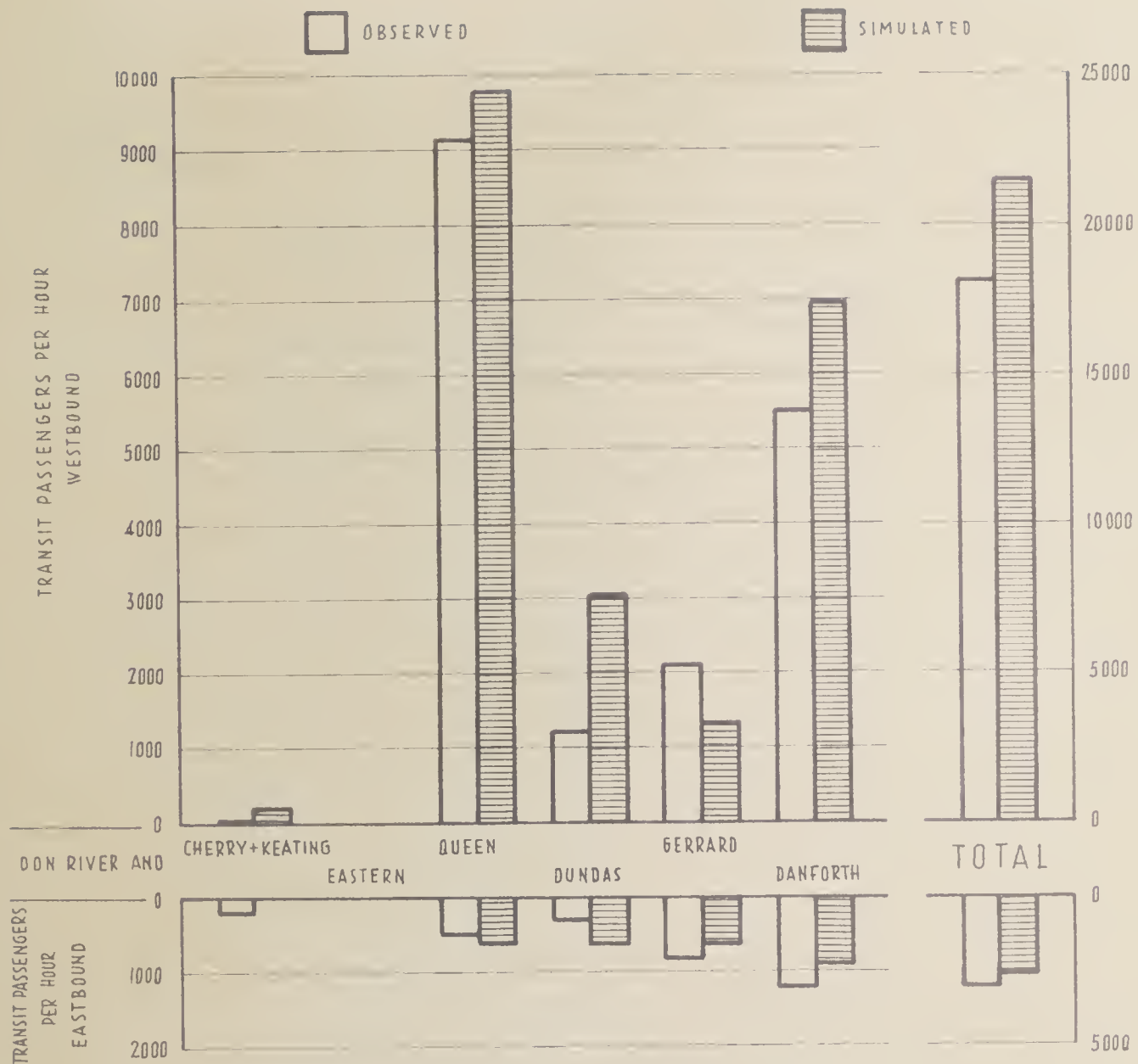
**AUTOS AND TRUCKS CROSSING NORTH TORONTO CORDON
DURING A.M. RUSH HOUR IN 1956**



**TRANSIT PASSENGERS CROSSING NORTH TORONTO COROON
DURING A.M. RUSH HOUR IN 1956**



AUTOS AND TRUCKS CROSSING DON VALLEY CORDON DURING A.M. RUSH HOUR IN 1956



TRANSIT PASSENGERS CROSSING DON VALLEY CORDON
DURING A.M. RUSH HOUR IN 1956

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APPENDIX I

CODING INPUT DATA

The following outline is not meant as a series of procedural instructions, but rather as a general guide to the sequence of steps to be followed in coding. The actual procedures themselves will vary to some extent depending upon the specific application of the model. It is felt however, that the sequence of operations used to process the raw data should not change.

Consequently, this outline will be of aid to the analyst in that it indicates when to deal with each phase of the coding. How to deal with each phase can be summarized in one word -, carefully! The specific procedures to be used can only be determined by the analyst after he has knowledge of these data available to him and is fully acquainted with the objectives of the study.

The general procedure to establish the transportation grid and land use data zones is as follows:-

1. A road grid must be drawn to the desired degree of comprehensiveness. Later on in the procedure roads may be omitted but the necessity of adding roads should not occur. Assume all intersections on the road grid to be nodes.
2. An overlay of basic data areas should be plotted. The smallest reasonable units should be used.

3. Assign each data area to the most representative intersection node. The data areas grouped about intersection nodes form zones and the nodes are known as zone nodes. Use natural barriers such as rivers, railroads, parks, cemeteries, etc., as a guide when combining areas.
4. Check each zone node for minimum and maximum standards. Adjust the nodal structure to comply with these requirements. Check the node total to be sure that it does not exceed the program limit.
5. Prepare a finalized node numbering system in the following sequence:
 - i) External Nodes - situated outside the actual study area but used to account for traffic entering or leaving the study area.
 - ii) Zone Nodes - representing data zones of the study area.
 - iii) Transfer Zone Nodes - rail commuter stations that also represent data zones.
 - iv) Transfer Intersection Nodes - rail commuter stations combined with road intersections.
 - v) Intersection Nodes - which represent link intersections only.

It is essential that a comprehensive checking system is established. The system should be based on the relative importance of each parameter and the method used to record the parameter originally.

Preparation of the Transportation Grid

a. Road grid

A detailed street map (1 inch = 2,000 feet) is used to prepare a basic road plan showing the expressways, arterial streets, major collector roads and other roads crossing

physical traffic barriers.

This basic road system comprises the most important roads in the area which carry at least 90% of the total vehicle miles travelled in the area. This system can be further abbreviated by combining the links of lesser roads with the links representing the major thoroughfares. The extent to which this is done would depend on the degree of refinement required in the road system in relation to the particular study.

Major cross-streets do not always exist between parallel widely spaced arterial roads. However, access is usually available through the use of several local streets. In such cases a link is inserted to indicate that a route does exist.

The basic principle underlying the grid coding is as follows:

A street intersection is represented by a node from which up to 6 links may emanate. A link can represent the travel path for one or both of the following travel modes.

1. Roads for passenger cars and trucks.
2. Transit routes for transit vehicles and commuter trains.

These modes are sub-divided to describe the types of facility in each:-

<u>Roads</u>	<u>Transit</u>
Type 1 - Arterials	Type 1 - Surface Transit or pedestrian
Type 2 - Expressways	Type 2 - Subway
	Type 3 - Rail commuter

For example, a link could represent an arterial road and the transit route operating on the road. In the Traffic Prediction Model the uses of the link are identified by using a code for each mode. Other combinations of link use can be employed, the only limitations being that a single link cannot represent more than one type of road and public transportation facility.

b. Transit grid

Every link appearing in the road grid must appear in the transit grid either as a transit vehicle route or a pedestrian route. The road links containing transit service are obtained from a public transit route map. Where a transit route uses a road not included on the basic road map the transit route is assigned to the road links which most closely follow the transit route. An attempt is made to assign transit routes to these links so as to indicate the accessibility of transit in an area consistent with actual conditions.

Links which do not contain transit routes are considered to be "pedestrian" links (i.e. - links where walking is the only form of transit available). Thus, expressways not having a transit service would be considered to be pedestrian links. Although expressways do not in fact provide for pedestrian traffic it is reasoned that pedestrians will be able to utilize the parallel local streets. Walking speed is assumed to be 3 miles per hour.

Where a link represents a subway no other form of transit may be recorded on that link. Where a subway coincides with a road link but some nodes do not coincide with subway

stations, special by-pass subway links are created i.e. link 218-377 (see Figure # 1). Another situation requiring a special link is where a subway does not follow the link system but flows diagonally across a block (link 327-238; see Figure 2).

Two transit grids are prepared. One shows the number of transit vehicles per hour utilizing each link and the other indicates (by different coloured lines) the breakdown of transit by vehicle classification as follows:

1. Surface
 - (a) Bus
 - (b) Streetcar
 - (c) Pedestrian
2. Subway

Because rail commuter operations closely resemble the public transit operation, it is considered as part of the transit system. The significant differences are fare structure higher commuter speed and greater distance between stations.

c. Transportation grid nodes

All intersections on the road grid are indicated by nodes with the exception of intersections where there is no access from one road to the other (e.g. underpasses or overpasses on expressways).

Zone nodes (i.e. nodes with land use data attached to them) may also be placed at any point on the road grid.

It is not desirable that zone nodes coincide with expressway interchange nodes. This is because movements off and on the expressway cannot be readily observed when a zone node is placed directly on the interchange. When an express-

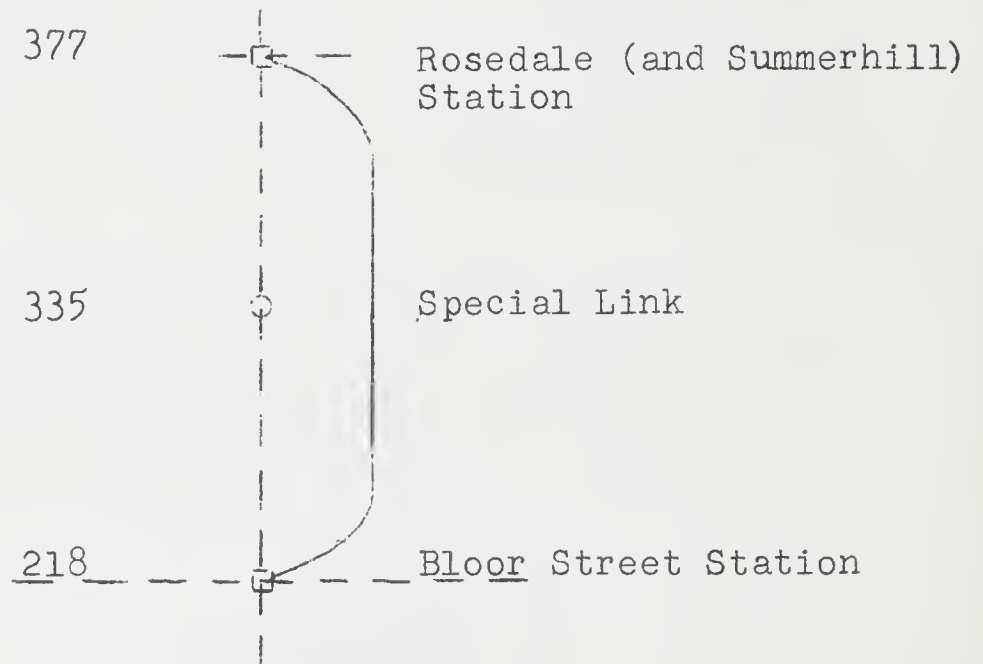


Figure 1

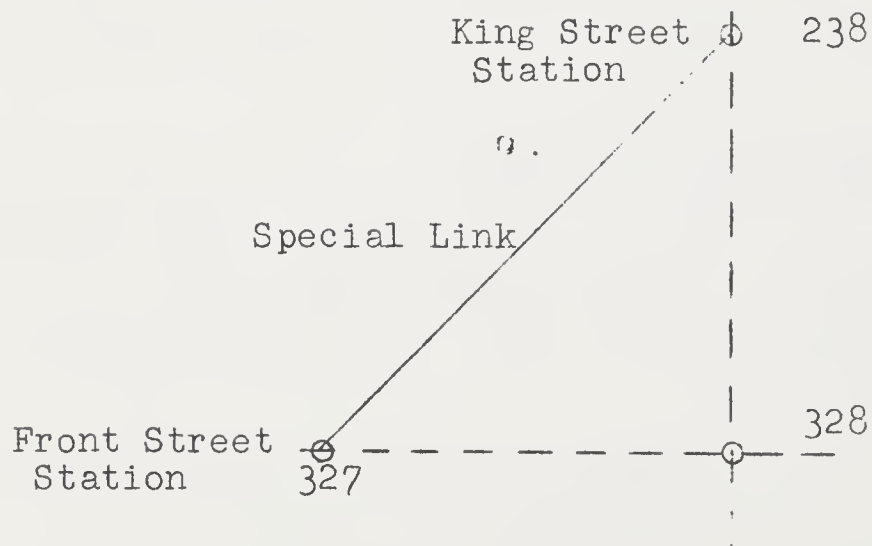


Figure 2

way node is suitably located for a zone node, an intersection node is placed on the expressway and a zone node placed adjacent to it on one of the cross-links.

Where nodes are plentiful (limitation 600) it would be desirable not to use a rapid transit station node to also identify a zone node. However, in the event that station nodes must serve a dual function, they should all be zone nodes. This overcomes some distortion of link passenger loads that occur where some stations serve a dual purpose and others a single node purpose.

Data Areas and Zone Nodes

Overlays are prepared to show census tracts, enumeration areas or other suitable data areas. The overlays are placed on the road grid and the data areas attached to the closest or most suitably located nodes. Although the closest intersection node is mostly used, physical traffic barriers between the intersection node and the data area may require a more distant node to be selected so as to ensure realistic traffic movements. All data areas are eventually grouped into data zones, each of which is represented by a zone node. Thus, in most cases the intersection node also representing the data zone falls within the zone area.

To obtain zone data the land use data listed by data areas are recorded on punch cards and zone totals calculated.

Data sheets are prepared and the corresponding information for each zone node are entered. Each zone node is then analyzed for minimum and maximum standards which should be

established for each study. These standards generally indicate the populations and/or employment levels below or above which zone totals should not fall. If a zone has totals lower than the minimum, it may be combined with a neighbor zone. Ideally, any zone exceeding the maximum should be re-distributed so as to lower the ratio. However, high densities primarily occur consistently throughout a large employment area (e.g. the C.B.D.). Consequently, the best alternative is to divide the total population of such an area into two or more zones, thereby distributing the flow among several links.

In recording land use data for the zones, the finest breakdown of data is by the enumeration area. When enumeration areas are not available or are too small, a complete census tract or subzone is used.

External nodes are placed at a pre-determined distance outside the study area. This is done to put the travel time from an external node at a level which would produce a wide distribution of trips within the grid. The only data associated with these nodes are an estimate of inbound and outbound person trips and average income.

At this stage a finalized system of nodes which are numbered for identification is evolved and a map drawn to show zones and location of nodes.

Input Data

The following is a list of the parameters used as input for the Traffic Prediction model:

a. Transportation Facilities Link Data

- 1) Capacity code
- 2) Number of lanes
- 3) Mode code
- 4) Number of transit vehicles per hour
- 5) Link length
- 6) Transit travel time

b. Land Use Zone Data

- 1) Population
- 2) Dwelling units
- 3) Residential acres
- 4) Cars
- 5) Total employment
- 6) Wholesale employment
- 7) Retail employment
- 8) Developed acres
- 9) Income
- 10) Miles of transit track
- 11) Transit stop spacing

a. Transportation Facilities Link Data1. Capacity code

The capacity code is based on three parameters:-

- (i) Type of surface vehicular transit on link
(i.e. - bus, streetcar or none)
- (ii) Speed limit (30, 40, 50 or 60 miles per hour)
- (iii) Number of signalized intersections per mile

The type of transit is a classification solely for the 30 mph speed limit category. The other categories (i.e. 40, 50 and 60 mph) do not differentiate between roads with or without transit.

The speed limit is the actual speed limit existing.

The number of signalized intersections per mile

(sipm) is determined by measuring the distance between adjacent traffic signals along the link. If the distance between signals is: less than 1/7.5 mile use 10 sipm; less than 1/4 mile but equal to or greater than 1/7.5 mile use 5 sipm; less than 1/2 mile but equal to or greater than 1/4 mile, use 1 sipm; equal to or greater than one mile, use 0 sipm.

Note that for all streets with a speed limit of 30 mph the lowest sipm classification is 1.

If a link is composed of sections of different categories of sipm, an average is taken. The result of the average is rounded to the nearest category.

2. Number of lanes

The method of determining the number of lanes is as follows:

- (i) Record the link in question
- (ii) Record the number of lanes on the street represented by the link
- (iii) Record the estimated critical flow on the adjacent local streets which supplement the link
- (iv) Record the critical capacity per lane of the link
- (v) Divide # 3 by # 4 to find the number of additional lanes
- (vi) Add # 2 and # 5 to obtain the total number of lanes for the link in question

The reason for using an estimated critical flow (iii) as the basis for adding lanes is because local streets cannot handle the same volume of traffic that an arterial street can. Consequently, the volume of traffic that produces the first trace of congestion on the arterial would produce noticeable congestion on the local street.

Critical capacities were obtained by dividing the metropolitan area into 3 zones - a CBD, inner ring, and the suburbs. The CBD was given an average of 10 sipm at 30 mph, the inner ring was given an average of 5 sipm at 30 mph and the suburbs were given an average of 2 sipm at 30 mph, then, by referring to the capacity table, the corresponding critical capacities were:

	<u>with streetcars</u>	<u>with buses & with no transit</u>
CBD	310	400
Inner Ring	360	450
Suburbs	460	550

3. Mode code

Each travel mode using a link is identified by a mode code, V, to represent vehicles, T, to represent trucks and Q to represent transit routes and rail commuter lines.

4. Number of transit vehicles per hour

The number of transit vehicles per hour on each transit link is determined either from the Toronto Transit Commission or estimated in relation to population density and proximity to subway stations. Where necessary these figures can be re-evaluated as the program progresses on the basis of passenger volumes assigned to transit links.

5. Link length

Link lengths were recorded from the base map in units of 100 feet. These units are consequently divided by 52.8 to obtain the link length in tenths of a mile.

6. Transit travel time

Surface transit links are given a travel time dependent on the speed of all traffic on the link as compared within the model.

Pedestrian links are given a fixed travel time of 20 minutes per mile (i.e. 3 mph).

Subway links are given a fixed travel time as determined by the T.T.C.

b. Land Use Zone Data

1. Population

Population is considered to be the total residential population and is initially recorded by data areas. Institutional population is not included because institutions (i.e. hospitals, reformatories, etc.) do not generate or attract a large amount of rush hour traffic regardless of their size. However, in several instances when the institutional population data of an area is very small and the total population very large, the extra work involved in removing the institutional population is not justified in terms of the degree of precision obtainable.

2. Dwelling units

Dwelling units are synonymous with households (i.e. any self-contained living unit). Dormitories and the like are regarded as one dwelling unit.

Institutional buildings, when recorded as dwelling units, were included in the data as such.

3. Residential acres

Residential acres include all land upon which dwelling units are found with one exception; when apartments are located above commercial establishments, the land use is classified as commercial.

4. Cars

For projection studies the number of cars per zone node are obtained by a formula derived from regression analysis of historic data.

$$\begin{aligned} \text{Number of cars} &= \left(\frac{.833 \text{ zone population}}{\text{Total population}} + \frac{.166 \text{ res. acres in zone}}{\text{Total res. acreage}} \right) \\ &\quad \times \text{Total Estimated} \\ &\quad \text{Car Population} \end{aligned}$$

5-7. Employment

The program uses three employment figures: whole-sale and manufacturing employment; retail, service and other employment; and total employment.

8. Developed acres

Developed acres is the total zone acreage minus the acreage of open space, vacant and agricultural land.

9. Income

Average income was found to be a most significant variable influencing a person's choice of travel mode. For this reason it was necessary to derive a means of estimating the average income level of each study zone from the available data. Income information was not obtained by the 1956 Home Interview Survey so that the most comprehensive data was that contained in the 1951 census.

These data were reported by census tracts which had to be first translated to data zones and then updated to 1956 income levels so as to be comparable with survey data. The average income per census tract is derived in the following manner.

The average income of male workers was multiplied by the total number of male workers. The average income of female workers was multiplied by the total number of female workers. The number of male and female self-employed was multiplied by 1.5 times the average income of male and female self-employed, respectively. This was done for each census tract. The sum of the products of each individual census tract was divided by the total employment of the census tract to obtain the average income per census tract.

The average income per zone is determined by a weighted average as follows:

$$l \text{ average} = \frac{P_a I_a + P_b I_b + \dots P_n I_n}{P_a P_b + \dots P_n}$$

where

P_a, P_b, \dots, P_n = data area population

I_a, I_b, \dots, I_n = average income of census tract as of 1951

The 1951 census tract median income was next updated to 1956. Since car ownership in each zone was found to be related to income level the percentage increase in car registrations from 1951 to 1956 was used as a factor to adjust the income level in each zone.

While the income level obtained by this means does not account for non-salary income, it is the best that could be derived from the available information. It is intended that income data obtained by the 1961 census will be used to re-evaluate the influence of income levels on travel characteristics.

10. Miles of track

The grid node map is overlaid on the transit grid. The total length of the vehicular transit routes contained in each nodal area is recorded. When a transit route occurs on the border of two nodes, it is considered to be a part of both nodes. This is because miles of track are used to determine the level of service of transit within each nodal area; consequently, when a transit route occurs on the border of two nodes, both nodes receive the full benefit of the service on the transit route.

11. Transit stop spacing

The stop spacing is used for determining the average walking distance to transit stops within the zone.

The stop spacing was set at 700 feet within the one-fare zone and 900 feet outside of the one-fare zone.

The one-fare zone was marked off on the nodal area map. In cases where the one-fare zone border occurred within a nodal area, the category (i.e. one fare or more than one fare) containing the majority of the area of the node was taken to be representative of the node as a whole.

APPENDIX II

TRIP GENERATION

Analysis of Survey Data

Factual data reported by the 1956 Home Interview Survey were used in conjunction with specified land use data to derive reliable trip generation formula. In the analysis of data all factors considered to have any bearing upon trip generation were scrutinized. The formulas subsequently derived predict the number of person trips originating in and attracted to each zone in relation to the zone characteristics that motivate such trips.

The survey reported all trips in ten purpose categories. An explanation of each of these is given in Appendix III - Home Interview Survey.

- | | |
|-----------------------------|---------------------------|
| 1. Work | *6. Change of travel mode |
| *2. Business | *7. Serving a passenger |
| *3. Doctor or dentist visit | *8. Shopping |
| *4. School | 9. Home |
| 5. Social or recreational | *10. Other |

Seven of these purpose categories, shown by asterisk, comprised a small percentage of total trips. Subsequent studies also indicated a reasonable similarity in the travel characteristics of this group. For these reasons, as well as to limit the required number of formulas, the ten purpose categories were reduced to four, as follows:

Work	1	(W)
Business, Commercial, Others	2,3,4,6,7,8,10	(BCO)
Social, Recreation	5	(SR)
Home	9	(H)

The expanded person trips reported by the survey are shown in Table 1, by origin to destination purposes, for all day and peak traffic periods 7-9 a.m. and 4-6 p.m. The significance of trips between home and work made during the a.m. and p.m. peak periods is readily evident. During the two-hour a.m. period, trips from home to work accounted for 73% of total trips with only 2% of total trips being made from work to home. During the p.m. period trips from work to home accounted for 65% of all trips.

It is also significant that the more predictable trips to and from home comprise 94% of all a.m. period trips and 89% of all p.m. period trips. The less predictable trips that are made between purposes other than home therefore comprise small percentages of 6% and 11% respectively for the two periods.

It is apparent that all trips can be divided into two categories; those having 'home' as either the trip origin or destination and those having other than 'home' as either the trip origin or destination. These two groups have been referred to as Primary and Secondary trips respectively. The primary trips are further subdivided by outbound and inbound movements. Thus:-

Outbound primary trips that originate at home	OP
Inbound primary trips that end at home	IP
Secondary trips that do not have a terminus at home	S

Person trips reported in the survey were indexed by starting time of trip in accordance with the following time periods:

TABLE I

TRIPS BY ORIGIN AND DESTINATION PURPOSE, ALL DAY,
A.M. AND P.M. PEAK PERIODS
(Home Interview Survey 1956)

Origin to Destination Trip Purpose	<u>All Day</u>		<u>7 - 9 A.M.</u>		<u>4 - 6 P.M.</u>	
	Total Trips	% of Total Trips	Total Trips	% of Total Trips	Total Trips	% of Total Trips
a) <u>Primary Trips</u>						
H to W	430,989	26	284,365	73	9,278	2
H to BCO	215,755	13	67,798	18	15,177	4
H to SR	102,557	6	1,616	-	5,939	1
W to H	409,280	24	6,728	2	281,563	66
BCO to H	209,645	12	3,403	1	61,094	14
SR to H	109,678	6	152	-	10,345	2
Sub-total Primary Trips	1,477,904	87	364,062	94	383,396	89
b) <u>Secondary Trips</u>						
W to BCO	34,561	2	576	-	20,952	5
W to SR	6,548	-	86	-	3,031	1
BCO to W	28,393	2	15,860	4	1,376	-
BCO to SR	13,043	1	278	-	1,807	-
SR to W	2,240	-	13	-	197	-
SR to BCO	11,077	1	92	-	1,453	-
W to W	43,895	3	1,912	-	4,456	1
BCO to BCO	46,953	3	4,530	1	11,879	3
SR to SR	12,060	1	90	-	787	-
Sub-total Secondary Trips	198,770	13	23,437	6	45,938	11
TOTAL	1,676,674	100	387,499	100	429,334	100

% of trips under 1% not indicated.

All day

7 - 9 A.M.

4 - 6 P.M.

All day excluding 7 - 9 A.M. and 4 - 6 P.M.

Person trips were also indexed by mode of travel as follows:

By automobile; car driver, car passenger, taxi passenger, truck passenger

By public transportation; passengers in buses, streetcars, subways and trains

The number of person departures and arrivals at all zones were correlated with the following survey and census data:

Population	P
Population at least 5 years of age	P5
Dwelling Units	D
Car Ownership	C
Total Employment	E _t
Wholesale Employment	E _w
Retail Employment	E _r

The following are the six types of person trips for which prediction formulas have been derived.

1. a) Persons leaving their zone of residence; referred to as outbound primary (OP) departures.
b) Persons returning to their zone of residence; referred to as inbound primary (IP) arrivals.
2. a) Persons leaving a zone for their zone of residence; referred to as inbound primary (IP) departures.
b) Persons arriving in a zone from their zone of residence; referred to as outbound primary (OP) arrivals.
3. a) Persons not resident in the zone leaving the zone for a destination other than their place of residence; referred to as secondary (S) departures.

- b) Persons not resident in the zone arriving at the zone from places other than their place of residence; referred to as secondary (S) arrivals.

Multiple regression analysis were carried out and formulas obtained for these six types of trips, by the time period of the day and by trip purpose. The numbers shown in the following table refer to the reference number of the formulas given below.

Trip Type	<u>7 - 9 A.M.</u>				<u>4 - 6 P.M.</u>				<u>All Day</u>
	<u>W</u>	<u>BCO</u>	<u>SR</u>	<u>All Purposes</u>	<u>W</u>	<u>BCO</u>	<u>SR</u>	<u>All Purposes</u>	<u>All Purposes</u>
1a	5 _b	5 _c	5 _d	5 _a	10 _b	10 _c	10 _d	10 _a	2
b	9 _b	9 _c	9 _d	9 _a	14 _b	14 _c	14 _d	14 _a	
2a	8 _b	8 _c	8 _d	8 _a	13 _b	13 _c	13 _d	13 _a	3
b*	6 _b	6 _c	6 _d	6 _a	11 _b	11 _c	11 _d	11 _a	
3a	7 _b	7 _c	7 _d	7 _a	12 _b	12 _c	12 _d	12 _a	4
b*	6 _b	6 _c	6 _d	6 _a	11 _b	11 _c	11 _d	11 _a	

* For trip type 2b and 3b only combined formulas were established

The following are the multiple regression formulas found for each trip type. The multiple correlation coefficient indicates the degree of reliability of each.

Ref.
No.

1. Trip generation, all day to all destination trip purposes.

$$(OP + IP + S) = -10.74499 + 0.69554 P_5 + 1.16924 D + 3.81172 C$$
(Multiple Correlation Coefficient = 0.95)

A.II-6

2. OP Departures, all day to all destination trip purposes.

$$OPD = - 4.52008 + 0.45184 P_5 + 0.16155 D + 0.92655 C$$

(Multiple Correlation Coefficient = 0.97)

3. IP Departures, all day from all origin trip purposes.

$$IPD = +265.46082 + 0.09026 P + 0.484591 E_t - 1.39300 E_w \\ + 0.80377 E_r$$

(Multiple Correlation Coefficient = 0.90)

4. S Departures, all day to all destination trip purposes.

$$SD = + 22.97164 + 0.09490 P + 0.11504 E_t + 0.00959 E_w \\ - 0.01722 E_r$$

(Multiple Correlation Coefficient = 0.72)

Trip generation for the time period 7-9 A.M.

5. OP Departures 7-9 a.m. to the destination trip purposes.

- a) All Purposes

$$OPD = - 2.42094 + 0.21339 P_5 + 0.23561 D + 0.27249C$$

(Multiple Correlation Coefficient = 0.96)

- b) Work (W)

$$OPD_w = - 2.47438 + 0.24004 P_5 + 0.34511 D - 0.23008C$$

(Multiple Correlation Coefficient = 0.96)

- c) Business, Commercial, Others (BCO)

$$OPD_{BCO} = - 0.04785 - 0.02984 P_5 - 0.09013 D + \\ 0.48687 C$$

(Multiple Correlation Coefficient = 0.76)

d) Social and Recreational (SR)

$$OPD_{SR} = + 0.03451 + 0.00182 P_5 - 0.01269 D + 0.01302C$$

(Multiple Correlation Coefficient = 0.13)

6. OP + S Arrivals 7-9 a.m. at the destination trip purposesa) All Purposes

$$OPA + SA = + 136.04473 + 0.00890 P + 0.30995 E_t + 0.08887 E_w + 0.38392 E_r$$

(Multiple Correlation Coefficient = 0.92)

b) Work (W)

$$(OPA + SA)_W = + 91.55606 - 0.02073 P + 0.30351 E_t + 0.25061 E_w + 0.29139 E_r$$

(Multiple Correlation Coefficient = 0.94)

c) Business, Commercial, Others (BCO)

$$(OPA + SA)_{BCO} = + 97.01079 + 0.02579 P + 0.00609 E_t - 0.13597 E_w + 0.08580 E_r$$

(Multiple Correlation Coefficient = 0.49)

d) Social and Recreational (SR)

$$(OPA + SA)_{SR} = + 40.20307 + 0.00048 P - 0.00452 E_t - 0.07139 E_w + 0.01995 E_r$$

(Multiple Correlation Coefficient = 0.67)

7. S Departures 7-9 a.m., to the destination purposes.a) All Purposes

$$SD = + 35.16470 + 0.01088 P + 0.01206 E_t + 0.12569 E_w - 0.00287 E_r$$

(Multiple Correlation Coefficient = 0.38)

b) Work (W)

$$SD_W = +31.41301 + 0.00823 P + 0.01242 E_t + 0.00665 E_w - 0.00025 E_r$$

(Multiple Correlation Coefficient = 0.31)

c) Business, Commercial, Others (BCO)

$$SD_{BCO} = + 38.79400 + 0.00192 P - 0.00107 E_t + 0.00165 E_w + 0.00710 E_r$$

(Multiple Correlation Coefficient = 0.26)

d) Social and Recreational (SR)

Sufficient survey data was not available to establish this formula. However, the estimation of secondary departures for the purpose of social and recreation may be carried out in the following manner:

$$SD_{SR} = SD - SD_W - SD_{BCO}$$

8. IP Departures 7-9 a.m. from the origin trip purposes.a) All Purposes

$$IPD = + 41.56105 + 0.00174 P + 0.01035 E_t - 0.02138 E_w - 0.00219 E_r$$

(Multiple Correlation Coefficient = 0.41)

b) Work (W)

$$IPD_W = + 53.15640 + 0.00023 P + 0.01106 E_t - 0.03141 E_w - 0.00341 E_r$$

(Multiple Correlation Coefficient = 0.40)

c) Business, Commercial, Others (BCO)

$$\text{IPD}_{\text{BCO}} = + 25.83529 + 0.00343 P - 0.00079 E_t + 0.02230 E_w - 0.00033 E_r$$

(Multiple Correlation Coefficient = 0.36)

d) Social and Recreational (SR)

$$\text{IPD}_{\text{SR}} = \text{IPD} - \text{IPD}_w - \text{IPD}_{\text{BCO}}$$

9. IP Arrivals 7-9 a.m. from the origin trip purposes.a) All Purposes

$$\text{IPA} = - 0.00300 + 0.00976 P_5 - 0.02638 D + 0.02840 C$$

(Multiple Correlation Coefficient = 0.57)

b) Work (W)

$$\text{IPA}_w = - 0.01748 + 0.01593 P_5 - 0.03384 D - 0.00089 C$$

(Multiple Correlation Coefficient = 0.46)

c) Business, Commercial, Others (BCO)

$$\text{IPA}_{\text{BCO}} = + 0.01128 - 0.0064a P_5 + 0.00805 D + 0.02919 C$$

(Multiple Correlation Coefficient = 0.50)

d) Social and Recreational (SR)

$$\text{IPA}_{\text{SR}} = + 0.00320 + 0.00025 P_5 - 0.00058 D + 0.00010 C$$

(Multiple Correlation Coefficient = 0.01)

Trip Generation for the Time Period 4-6 P.M.10. OP Departures 4-6 p.m. to the destination trip purposesa) All Purposes

$$\text{OPD} = - 0.07575 + 0.02354 P_5 - 0.07667 D + 0.10645 C$$

(Multiple Correlation Coefficient = 0.76)

b) Work (W)

$$OPD_W = - 0.09226 + 0.02551 P_5 - 0.05638 D + 0.00281C$$

(Multiple Correlation Coefficient = 0.61)

c) Business, Commercial, Others (BCO)

$$OPD_{BCO} = - 0.00973 - 0.00001 P_5 - 0.04107 D + 0.09863 C$$

(Multiple Correlation Coefficient = 0.62)

d) Social and Recreational (SR)

$$OPD_{SR} = + 0.03173 - 0.00343 P_5 - 0.02634 D + 0.00354 C$$

(Multiple Correlation Coefficient = 0.33)

11. OP + S Arrivals 4-6 p.m. at the destination of trip purposes.

a) All Purposes

$$OPA + SA = + 39.75915 + 0.03206 P + 0.01213 E_t - 0.10271 E_w + 0.06061 E_r$$

(Multiple Correlation Coefficient = 0.63)

b) Work (W)

$$(OPA + SA)_W = + 27.13445 + 0.00267 P + 0.00670 E_t - 0.02602 E_w + 0.02138 E_r$$

(Multiple Correlation Coefficient = 0.81)

c) Business, Commercial, Others (BCO)

$$(OPA + SA)_{BCO} = + 54.34389 + 0.02288 P + 0.00277 E_t - 0.02495 E_w + 0.02192 E_r$$

(Multiple Correlation Coefficient = 0.39)

d) Social and Recreational (SR)

$$(OPA + SA)_{SR} = + 47.13561 + 0.00648 P + 0.00130 E_t - 0.04742 E_w + 0.01544 E_r$$

(Multiple Correlation Coefficient = 0.40)

12. S Departures, 4-6 p.m. to the destination trip purposes.a) All Purposes

$$SD = + 49.01141 + 0.01211 P + 0.04445 E_t - 0.01270 E_w - 0.01295 E_r$$

(Multiple Correlation Coefficient = 0.72)

b) Work(W)

$$SD_w = + 47.24281 + 0.00305 P - 0.00334 E_t + 0.00574 E_w + 0.00514 E_r$$

(Multiple Correlation Coefficient = 0.24)

c) Business, Commercial, Others (BCO)

$$SD_{BCO} = + 51.19643 + 0.00808 P + 0.04265 E_t - 0.03459 E_w - 0.02443 E_r$$

(Multiple Correlation Coefficient = 0.66)

d) Social and Recreational (SR)

$$SD_{SR} = + 58.54932 - 0.00001 P + 0.00556 E_t - 0.03705 E_w + 0.01020 E_r$$

(Multiple Correlation Coefficient = 0.72)

13. IP Departures 4-6 p.m. from the origin trip purposes.a) All Purposes

$$IPD = + 170.32479 - 0.01369 P + 0.30379 E_t - 0.20232 E_w + 0.38736 E_r$$

(Multiple Correlation Coefficient = 0.93)

b) Work (W)

$$\text{IPD}_W = + 113.94665 - 0.02918 P + 0.28360 E_t + 0.16645 E_W + 0.26817 E_r$$

(Multiple Correlation Coefficient = 0.94)

c) Business, Commercial, Others (BCO)

$$\text{IPD}_{\text{BCO}} = + 101.27961 + 0.00923 P + 0.01771 E_t - 0.34111 E_W + 0.11082 E_r$$

(Multiple Correlation Coefficient = 0.61)

d) Social and Recreational (SR)

$$\text{IPD}_{\text{SR}} = + 65.23446 + 0.00200 P + 0.01779 E_t - 0.09521 E_W - 0.00054 E_r$$

(Multiple Correlation Coefficient = 0.19)

14. IP Arrivals 4-6 p.m. from the origin trip purposes.

a) All Purposes

$$\text{IPA} = - 1.86492 + 0.26089 P_5 + 0.29011 D - 0.02247 C$$

(Multiple Correlation Coefficient = 0.97)

b) Work (W)

$$\text{IPA}_W = - 1.60632 + 0.29510 P_5 + 0.22308 D - 0.35484 C$$

(Multiple Correlation Coefficient = 0.96)

c) Business, Commercial, Others (BCO)

$$\text{IPA}_{\text{BCO}} = 0.35645 - 0.03453 P_5 + 0.03578 D + 0.33148 C$$

(Multiple Correlation Coefficient = 0.78)

d) Social and Recreational (SR)

$$IPA_{SR} = + 0.09627 - 0.00355 P + 0.03796 D + 0.00432 C$$

(Multiple Correlation Coefficient = 0.42)

Using the above trip generation formulas it is possible to estimate peak period and all day person trips. However, some estimates will be more reliable than others. Using the multiple correlation coefficient as an indicator of reliability, it is possible to rank these estimates. With few exceptions it is observed that the multiple correlation for work trips (origin or destination purpose) is ranked highest, followed by that of BCO trips.

Although it is possible to estimate person trips for both the AM and the PM peak hours, it is concluded that trip estimates for the AM period are more reliable. During the AM period all trips from home to work, business, commercial and other purposes comprise 90% of total trips as compared to 82% in the PM period.

Estimates of the AM period traffic are obtained by using the respective trip generation equations. The estimates for an average rush hour are obtained then by dividing the estimates by two. Findings of the trip generation analysis were used for the test run of 1956 and prediction run for 1980.

When using the trip generation formulas in the Trip Generation Block, the following procedure was followed:

1. Combine the formulas of section 5 and 7 to provide estimates of the summed figure (OPD + SD). There is no loss in accuracy of estimation by this step.

2. Rather than estimate inbound primary trip departures (IPD) by purpose, do so in total. Since IPD are 4% of the total traffic (See Table I), there is little loss in accuracy of estimation to be expected.

These two steps reduce the number of generator figures from fifteen to eight, thereby minimizing the number of trip purposes in the program while incurring little loss in the accuracy of traffic estimation. The four origin-destination purposes as used in the test run are as follows:

G_1 . Home, Work, BCO, SR to Work

G_2 . Home, Work, BCO, SR to BCO

G_3 . Home, Work, BCO, SR to SR

G_4 . Work, BCO, SR to Home

Generator figures G_1, G_2, G_3, G_4 , and corresponding attractor figures A_1, A_2, A_3, A_4 , are calculated by solving the following formulas upon substitution of the appropriate land use data:

Generator formulas

$$G_1 = +14.469315 + 0.004115P + 0.120020P_5 + 0.172555D - 0.115040C \\ + 0.006210E_t + 0.003325 E_w - 0.000125E_r$$

$$G_2 = +19.373075 + 0.000960P - 0.014920P_5 - 0.045065D + 0.243435C + \\ + 0.000535E_t + 0.000825E_w + 0.003550E_r$$

$$G_3 = +0.017255 + 0.000910P_5 - 0.006345D + 0.006510C$$

$$G_4 = +20.780525 + 0.000870P + 0.005175E_t - 0.010690E_w - 0.001095E_r$$

Attractor formulas

$$\begin{aligned}
A_1 &= +45.778030 - 0.010365P + 0.151755E_t + 0.125305E_w + 0.145695E_r \\
A_2 &= +48.505395 + 0.012895P + 0.003056E_t - 0.067985E_w + 0.042900E_r \\
A_3 &= +20.101535 + 0.000240P - 0.002260E_t - 0.035695E_w + 0.009975E_r \\
A_4 &= 0.001500 + 0.004880P_5 - 0.013190D + 0.014200 C
\end{aligned}$$

Before the generated trips are used in the Traffic Prediction Model they are used to normalize the attractors so that the total number of attractors is equal to the total number of trips generated. This normalization of the attractors is necessary to ensure convergence of the trip interchange calculations.

Results of Test of Trip Generation Model

Tests were made to show that estimated trip departures were within variability limits of expanded survey trips. Estimates were made for selected areas of Metropolitan Toronto, and compared with expanded survey trips reported for the areas. The areas were as follows:

1. Mimico, New Toronto, Long Branch, southern sections of Etobicoke
2. East York
3. Sections of Scarborough
4. Weston, northern sections of Etobicoke
5. CBD of City of Toronto
6. Sections of Toronto to the west of the CBD

Table 2 shows that the estimated trips for program purposes G_1 and G_2 , but for one exception, are within variability limits of the expanded survey trips of the Home Interview Survey.

TABLE II

COMPARISON OF EXPANDED SURVEY TRIPS AND ESTIMATED TRIPS

Area	<u>Survey Trips G1</u>		Estimated Trips	<u>Survey Trips G2</u>		Estimated Trips
	<u>Expanded</u>	<u>Limits</u>		<u>Expanded</u>	<u>Limits</u>	
1	6700	5440- 7960	7898	2088	1388- 2788	2569
2	5375	3905- 6845	4282	671	195- 1147	1096
3	2615	1699- 3531	3530	1502	814- 2190	1143
4	2717	2001- 3433	2756	310	60- 560	1060
5	6041	4341- 7741	6586	809	185- 1433	1231
6	16600	14120-19080	16906	2265	1373- 3157	2584

TRIP DISTRIBUTION

Given the attractor and generator corresponding to each centroid node for each trip purpose and given the time factor for each O-D pair for each purpose, the Trip Distribution Block determines the total trips via all modes and for all purposes combined from each origin to each destination. These trips are first determined separately for each purpose and then added together to provide the "total trip interchange" for each O-D pair.

The number of trips between any two points for a particular purpose is dependent on the total number of trips generated for distribution at the origin for that purpose, G_i , the total number of trips attracted to the destination for the same purpose, A_j , and the time factor, $(TF)_{ij}$, describing the "friction" between the origin and destination for the particular purpose in question.

The following general formula is used to calculate trip interchange volumes:

$$J_{ij} = G_i A_j (TF)_{ij} \quad (1)$$

where:

- J_{ij} = number of trips going from origin i to destination j for the purpose in question.
- G_i = Total trips generated for this purpose at origin i .
- A_j = Total trips attracted for this purpose at destination j .

$(TF)_{ij}$ = Time Factor for the trip between origin i and destination j for this purpose.

This formula is the well known "gravity formula", so called because of its similarity to the formula derived by Newton to describe gravitational attraction between two masses.

There are two basic differences however. One is that Newton's formula replaces $(TF)_{ij}$ by $1/r_{ij}^2$, where r_{ij} is the distance between the two masses. As described above, the trip interchange formula used in this model employs instead a negative exponential function of the travel time, since this describes best the observed trip behaviour of urban travellers.

The other difference is more fundamental. If formula (1) is applied to a city in which all zones are equally spaced and have equal generators and equal attractors, and in which there are no edge effects, then the trip interchanges so calculated for each trip purpose would be such that:

$$\sum_{j=1}^{NUZN} J_{ij} = G_i \quad (2)$$

and

$$\sum_{i=1}^{NUZN} J_{ij} = A_j \quad (3)$$

That is, the sum of the trips leaving each zone would equal the generator at that zone and the sum of the trips arriving at each zone would equal the attractor at that zone.

However, real cities are not homogeneous as to zone

size and spacing, and some zones are always on the edge rather than in the middle, so that there are many zones for which conditions (2) and (3) are not met if equation (1) is used. For example, a zone closely surrounded by many large generator zones would probably tend to receive more trips than warranted by the size of its attractor. The fact that the attractor (the number of trips which can actually be received at the zone) is smaller than the arrivals which the unmodified gravity model would lead to it, is due to factors which the gravity model does not attempt to take into account. These could be space or accommodation limitations in the zone, or the fact that wages in the zone have been driven down by competition among the large number of workers who live in neighbouring zones and wish to work there.

Rather than trying to take these factors into account explicitly, the gravity formula is modified on an empirical basis to match the departures with the generator and the arrivals with the attractor for each trip purpose at each zone. This is done by a repetitive process, as follows:

Formula (4) is used in a first pass of the distribution algorithm* to obtain the first adjusted generators

$$G_i^{(1)} = \frac{G_i^{(0)}}{\frac{\text{NUZN}}{\sum_{j=1}^n \Lambda_j^{(0)} (TF)_{ij}}} \quad (4)$$

* An algorithm is a method of calculation following a systematic set of rules; it is a term often used to describe specific calculation routines used in a computer program.

During the first pass of the distribution algorithm, the generator and attractor figures are further adjusted for each zone by means of the following formulas:

$$A_j^{(1)} = \frac{A_j^{(0)}}{\sum_{i=1}^{NUZN} G_i^{(0)} (TF)_{ij}} \quad (5)$$

and

$$G_i^{(2)} = \frac{G_i^{(0)}}{\sum_{j=1}^{NUZN} A_j^{(1)} (TF)_{ij}} \quad (6)$$

where the superscript (0) refers to the unadjusted value of G or A, and (1) and (2) refer to adjusted values produced by the first pass of the distribution algorithm.

If after this first iteration of the distribution algorithm it is felt that matching is still insufficient as determined by the convergence criterion, formula (9), a second iteration is carried out, during which the generators and attractors are adjusted again. Successive iterations can be carried out as many times as necessary to achieve matching of desired accuracy.

Note: At the end of this iterative procedure the generators are adjusted (n + 1) times, while the attractor is adjusted only n times. This ensures that the departures will exactly match the generator at each zone, while the arrivals will approximately match each attractor with an accuracy depending on the number of distribution algorithm iterations carried out.

The adjusted generators and attractors produced by the n th iteration of the distribution algorithm are given by the following generalized forms of formulas (5) and (6):

$$A_j^{(n)} = \frac{A_j^{(0)}}{\sum_{i=1}^{NUZN} G_i^{(n)} (TF)_{ij}} \quad (7)$$

and

$$G_i^{(n+1)} = \frac{G_i^{(0)}}{\sum_{j=1}^{NUZN} A_j^{(n)} (TF)_{ij}} \quad (8)$$

where the superscripts $(n + 1)$ and (n) refer to adjusted values of G or A produced by the n th iteration. The table of adjusted generators and attractors, $G_i^{(n+1)}$ and $A_j^{(n)}$, produced by the last iteration of the trip distribution algorithm for each trip purpose, is written onto tape by the Trip Distribution Block and can be used as input for a subsequent run of Block 3 if desired. This could be done to save calculation time in the subsequent Block 3 run if congestion patterns in the study area have not changed appreciably during the intervening cycle.

Use of this trip distribution algorithm has shown that two iterations (i.e. the initial pass plus one repetition) are usually enough to match arrivals and attractors to within 5% for the majority of zones in the study area.

There are two criteria by which the analyst can

control the accuracy with which arrivals will be matched to attractors for each trip purpose. First, he can specify the value of ϵ (also called EPSI) below which a mathematical expression called the "epsilon convergence criterion" must drop before he will be satisfied. That is, he gives ϵ a value such that as soon as the condition

$$\frac{\sum_{j=1}^{NUZN} \left(1 - \frac{A_j^{(n)}}{A_j^{(n-1)}} \right)^2}{NUZN} \leq \epsilon \quad (9)$$

has been met the desired degree of accuracy will have been reached. Examination of equation (9) will show that the epsilon convergence criterion approaches zero as the arrivals match the attractor at more and more zones since the ratio $A_j^{(n)}/A_j^{(n-1)} = 1$ for each j at which such matching has occurred.

Second, he can specify the maximum number of iterations (NUIT) of the distribution algorithm to be allowed for the trip purpose in question.

Both NUIT and EPSI are specified by the analyst for each trip purpose. As soon as either criterion is met for a particular purpose no further iterations are carried out for that purpose. When the adjusted generators and attractors have been so calculated for each trip purpose, the trip interchanges for each O-D pair are calculated for each purpose by means of formula (1) and then summed over all purposes to produce the total trip interchange volumes for each O-D pair.

CHOICE OF TRAVEL MODE

People are influenced by many factors in their choice of travel mode. These factors will be characteristic of the relative travel time, the social-economic status of the population, the influence of relative costs on the population groups, and the regularity and convenience of service. Using regression analysis methods the influence of each of the factors was investigated separately and trends in transit usage were established.

Once mass human travel behaviour was sufficiently explained by various factors a mathematical model was designed to duplicate persons choice of travel mode.

Studies of Factors

The relative importance of factors identified from survey data is described in detail in the subsequent paragraphs. Only the major factors are mentioned, such as time, economic motivations, regularity and convenience of service. Other factors were eliminated from further investigations, once shown to be highly correlated with the major factors. Results of a study of these other factors are contained in a separate technical report.

1. Travel Time

People are conscious of time elapsed while travelling, consequently they are likely to choose the mode of travel that keeps this time to a minimum. If more than one travel mode is available the choice may be related to the difference

between the travel times of the two modes. Such an approach overlooks the relative importance of this difference between travel time increases. For example, a ten minute difference between travel times of ten and twenty minutes is more critical than between travel times of twenty and thirty minutes. The travel time difference between the two modes is therefore given as a percentage of one of the travel times. This is equivalent to saying peoples' choice of travel mode is related to the ratio of the travel times.

Work trips reported in the Worker Survey 1954 were studied to determine the percent usage of transit in relation to the travel times by both modes from each origin zone to all destination zones. Plate # 1 shows the graphic results of this study. As the travel time difference between automobile and transit increases, the percent of all work trips made by transit decreases. Thus, where the travel time difference is less than 1.0, the percentage of transit use is above 90%; where the travel time by transit is three times that of the automobile trips, then transit usage falls below 30%.

2. Economic Motivations

Travel cost is one of the considerations made when making a choice of travel mode. The importance of cost for each person is related to their economic status which at this time is measured by family income. One expects that people of low economic status are more conscious of travel costs than people of higher economic status who can afford more expensive modes. For changes in travel costs, such as increases in transit fares, people are likely to choose a new mode of travel, because either they find travelling by their

present mode is now too expensive or both modes are cost-wise equivalent and they are now more conscious of other factors such as relative travel time and the regularity and convenience of service.

Neither income statistics, nor comparative travel costs for each mode of travel were reported with the Workers' Survey. However, steps were taken to provide this information.

The Census Report of the Dominion Bureau of Statistics for the year 1951 provided information about the median incomes of male and female workers residing in each census tract. Although worker's income increased between 1951 and 1954, it was assumed that in 1954 workers still received the same income relative to their neighbours income. The 1951 income scales, uniformly graded up to 1954 standard of living, were assumed to reasonably represent peoples' economic status in 1954. The worker population of each urban zone was then assigned an economic indicator with a range of values from 0 to 35 dependent upon the median income calculated for each zone based on the census tract income.

Plate 2 shows the percentage of all work trips made by transit in relation to the economic indicator for the worker population. The fitted line which is shown to agree closely with the observations appears to have three segments. As is to be expected, the low economic indicators of the first segment show a high percentage use of transit. The second segment occurring between 10 and 20 indicates an almost complete levelling off of transit usage. Beyond the latter point transit usage again falls sharply with increasing economic indicators.

Since transit usage shows such close correlation with the economic indicators, it was considered that there must also be a relationship between transit usage, economic indicators and travel cost using the following sources of information:-

1. Public transit zone maps and fare tables.
2. Parking data obtained from the Parking Authority of Toronto and the Toronto Transit Commission provided information of the off-street and on-street parking supply and the corresponding parking charges. Relationships established from such data showed that parking costs increased as the demand for parking exceeded a given supply. These relationships were used to determine parking charges in other zones.
3. "Economic Evaluation of Traffic Networks", by G. Haikalis and H. Joseph. The review provided estimates of the operating costs of an automobile based upon speed and distance of travel. The operating cost was set equal to the sum of the running and accident costs. Running costs included gas, oil and maintenance expenses. High accident costs at low speeds of travel were expected to be representative also of travel discomfort experienced at these low speeds.

Regression analysis was conducted to correlate changes in transit usage with the difference in travel cost between auto and transit. Trends were disclosed that were approximately coincident with similar trends in transit usage for changing levels of the economic indicator. Constant increments of costs were shown to cause changes in transit usage that could be explained by a constant increment in the economic indicator. These findings supported the deduction that people of a set economic status do alter their travel behaviour when changes in costs of travel occur, so that their behaviour is similar to that of people of a different economic

status. It was concluded that the influence of changes in cost of travel would be reflected by a linear adjustment in the established economic indicator of the worker population.

3. Regularity and Convenience of Service

The private vehicle offers a more luxurious and convenient mode of travel than does public transportation, particularly by eliminating lengthy waiting periods and walking times. However, waiting periods and walking times are important considerations when using transit since they reflect the level of service offered on the public transportation facility. People tend to measure the regularity and convenience of public transportation service in terms of the time spent in addition to travelling, such as walking time from the trip origin to the station, waiting time at the station, transfer time between route changes, and walking time from the station to the trip destination.

The following steps were taken to calculate these measurements:

i) Waiting Times

The waiting time at a station is set equal to one half the scheduled headway time of the public transportation facility in a zone as recorded by the Toronto Transit Commission for rush hour service on October 4, 1955.

ii) Transfer Times

It is reported that approximately ninety percent of subway passengers make at least one transfer; approximately fifty percent of all transit passengers make one transfer,

and ten percent of this number make two or more transfers. Despite the introduction of a small error, each O-D transit movement is recorded with one transfer. This transfer time is set equal to one half the scheduled headway time of the public transportation facility in the destination zone.

iii) Walking Times

Although walking times were not reported in the surveys, there was sufficient information available to make possible the computation of average walking times to and from transit stations or stops; such as the number of miles of transit track, the average spacing between stations, and the number of acres of developed land in a zone. A few assumptions concerning the location of transit lines with respect to the zone boundaries and peoples' walking behaviour, were necessary for the estimation of these average walking times.

Since transit routes follow the rectangular road layout of the city it was assumed that approximately one half of the transit lines servicing a zone run north-south and the other half east-west. Also, one can assume that people tend to walk to the nearest transit station located on a transit route which runs parallel to their desired direction of travel.

If the north-south and east-west transit lines are evenly distributed throughout the same developed area, then the following formulas may be used to compute representative walking distances, and walking times, which people may experience in each zone.

The average distance walked in miles,

$$D = \frac{1}{3} \sqrt{d^2 + w^2} + \frac{d^2}{6w} \ln \left(\frac{d^2 + w^2 + w}{d} \right) + \frac{w^2}{6d} \ln \left(\sqrt{\frac{d^2 + w^2 + d}{w}} \right)$$

where:

d = $1/2$ x stop spacing, miles

$w = \frac{A_D}{L_T} \times \frac{1}{640}$, miles

A_D = Number of acres of developed land

= Total land - vacant land - open space

L_T = Number of miles of transit track or bus line

The average walking time in minutes,

$$T = \frac{60}{3} \times D \quad (\text{walking speed of 3 mph})$$

The level of transit service between each origin and destination is measured by the sum of the walking plus waiting time in the origin zone, a transfer time and the walking time in the destination zone.

Observations were grouped and plotted. A curve was drawn to show the relationship between transit usage and the changing levels of O-D transit service. (see Plate 3)

Development of Travel Mode Split Model

Knowledge of the order of magnitude of the factors which influence peoples' choice of travel mode is especially important if the mechanism at work in the Travel Mode Split is to be adequately explained. The trends in transit usage now established indicate the relative order of magnitude of the influence of the three factors:

1. relative travel time
2. economic indicator as recorded for the population (based on average travel costs)
3. level of transit service between origin and destination.

To formulate a mathematical model for the purpose of projection of transit usage the relationships between these factors and the transit share of person trips are united into a single model. The expected trends in travel behaviour are displayed in Plates 4 and 5.

The following conditions are satisfied by this model of Travel Mode Split:

Population groups indexed by a high economic indicator place more emphasis on time and comfort than cost considerations. Other population groups with a low economic indicator possibly ignore time and comfort considerations to choose a mode of travel which they can afford to use. This mechanism is duplicated in the model where transit usage by persons of high economic status is more elastic with changes in the travel time ratio than transit usage by persons of low economic status.

The transit usage reported in the Workers' Survey, was stratified by the economic status of the population and by levels of O-D transit service. Once the observations were stratified, transit usage was next correlated with the transit to automobile travel time ratio. The observations were assigned weights according to the number of person trips (unit = 1000) grouped together for each interval of time ratio. Curves were drawn through the plotted observations to demonstrate the trends in transit usage. (See Plates 4 and 5). Dotted lines are extrapolated beyond the range of observations to indicate the postulated trends.

Although these established trends are characteristic of work trips, further studies indicated that they approximately duplicate the behaviour of people who make business, commercial, or school trips in autos or on transit during the rush hour.

The behaviour of people making social trips appeared to differ from that of people making other types of trips.

It was noted in the analysis of the data of the Home Interview Survey that social trips were less than one percent of total trips made during the morning rush hour and three percent of total trips made during the evening rush hour. If the model is used to determine the transit usage during the morning rush hour the resulting discrepancy of calculating the transit share of social trips is negligible.

It is known that estimates of traffic for the morning rush hour are more reliable than the traffic estimates for the afternoon rush hour because of the predominance of work trips and the absence of other types of trips. It was concluded that curves for the estimation of the transit share of work trips, such as those illustrated in Plates 4 and 5 will give accurate forecasts for the morning rush hour.

Travel Mode Split in Time Factor Block

Thirty curves that describe the relationship between the transit share of traffic and the travel time ratio are expressed in table form for input to the Time Factor Block. Each curve describes the transit usage of a specific population group for a specific level of transit O-D service. The population is divided into five groups where the first group are people of low economic status, and the fifth group are people of high economic status. There are six levels of transit O-D service, the first representative of very regular

and convenient service, the sixth representative of irregular and inconvenient service.

To calculate the transit and vehicular share of traffic for the a.m. rush hour the order of steps is as follows:

1. The economic indicator that is representative of the population residing in a home zone is linearly adjusted by a multiple of the travel cost difference for each O-D movement. The travel cost difference equals the sum of operating, accident and parking costs minus the transit fare.

2. The regularity and convenience of service is measured by the sum of waiting, transfer, and walking times likely to be experienced in each O-D movement. The waiting time is set equal to one half the average headway time of the transit facility in the origin zone. Walking times are calculated for both the origin and destination zone, then added together. One transfer time is included, this is set equal to one half the average headway time of the transit facility in the destination zone of the traffic.

3. Average O-D travel times are calculated for the vehicle mode and the transit mode. Transit O-D travel time is divided by the vehicular O-D travel time to form the travel time ratio.

4. The adjusted economic indicator and the level of O-D transit service specify the travel mode split table to be used. The travel time ratio then indexes the transit share of each O-D movement.

Further details of the development of the travel modes are presented in a separate technical report.

ROUTE ASSIGNMENT FACTORS

Traffic assignment is a term applied to the method of calculating the number of vehicles or persons that would use a given transportation facility under certain given travel conditions.

In the Traffic Prediction Model the problem of assignment consists of determining the number of vehicles or persons using each of two or more routes for the same travel mode, given the origin-destination trip for the particular mode. $(AF)_1$, the first assignment factor, indicates what proportion of the trips going from an O to a D via a particular mode will travel via the first route available between that O and D for the mode in question. For example, assume that a given prediction run has constructed 3 vehicle routes, 2 transit routes and 1 combined transit-vehicle route between each O-D pair. In this case $(AF)_1$, $(AF)_2$ and $(AF)_3$ for a given O-D pair would indicate what proportion of the private vehicle travellers going from the origin to the destination would use each of the 3 vehicle routes available for that O-D pair; $(AF)_4$, $(AF)_5$ and $(AF)_6$ would indicate what proportion of the public transit travellers would use the first and second transit routes and the combined transit-vehicle route.

It can be seen that assignment factors are required only for a mode which has two or more routes available for any O-D pair. For such a mode there is an assignment factor for each route to specify the proportion of travellers within that mode using the route.

The assignment factors are used in Block 4 together with the modal split factors, to determine the split trips from each origin to each destination in the area under study.

Assignment factors are calculated in Block 2, using the route travel times for each O-D pair obtained from Block 1, by means of the following formula:

$$(AF)_1 = \frac{\left(\frac{1}{T_1}\right) a(V)}{\left(\frac{1}{T_1}\right) a(V) + \left(\frac{1}{T_2}\right) a(V) + \dots + \left(\frac{1}{T_n}\right) a(V)} \quad (1)$$

where:

$(AF)_1$ is the assignment factor for route 1. (Specifying what percentage of private vehicle travellers are using the first vehicle route for the O-D in question);

T_n is the travel time via the nth route from the O to the D. (There is a total of n routes for the O-D pair in question);

$a(V)$ is the assignment factor exponent for vehicles which is empirically determined and specified by the analyst.

It can be seen that the proportional assignment is another means by which capacity restraints are taken into account in this prediction model. Although the shortest route from an O to a D will have the shortest travel time under non-loaded conditions, its popularity may lead to traffic congestion which increases its travel time to a higher value than that for the other available routes. The proportional assignment allows this effect to be simulated in a reasonable manner.

For determining assignment factors within the transit mode, $a(Q)$ would replace $a(V)$ in formula (1) above.

Note: For a given mode the sum of the calculated assignment factors for a given O-D pair is always equal to 1; i.e.

if there are four vehicle routes (V) and two transit routes (Q) available for each O-D pair, then for the V mode for each O-D pair:-

$$(AF)_1 + (AF)_2 + (AF)_3 + (AF)_4 = 1 \quad (2)$$

and for the Q mode

$$(AF)_5 + (AF)_6 = 1 \quad (3)$$

Capacity Function

The term "capacity function", means the mathematical formula developed to describe the relationship between traffic volume and travel time for a given road section called link. Flow of vehicles along a road is a very complex phenomenon, depending on many factors. Each road section is probably unique in its combination of factors effecting the flow and should, for precise simulation, have a unique capacity function not only for various speed limits, number of signalized intersections per mile, number of lanes and presence of public transit but also for different time periods and different weather conditions, etc. Perhaps computer capacity and empirical data will be sufficient someday for this degree of precision.

For our purpose, however, we have approximated it as follows:

When large numbers of vehicles are attempting to use a given road section, the speed at which they can travel is materially reduced, a phenomenon which is known as traffic congestion. For any road section it is possible to measure the relationship between the volume or flow, of vehicles traversing the link (cars per hour per lane) and the resulting

travel time in minutes per mile. Two typical volume-time relationships of this type are illustrated in Figure 1, where f is the per-lane flow of vehicle and t is the resulting travel time per mile, known as the per unit travel time.

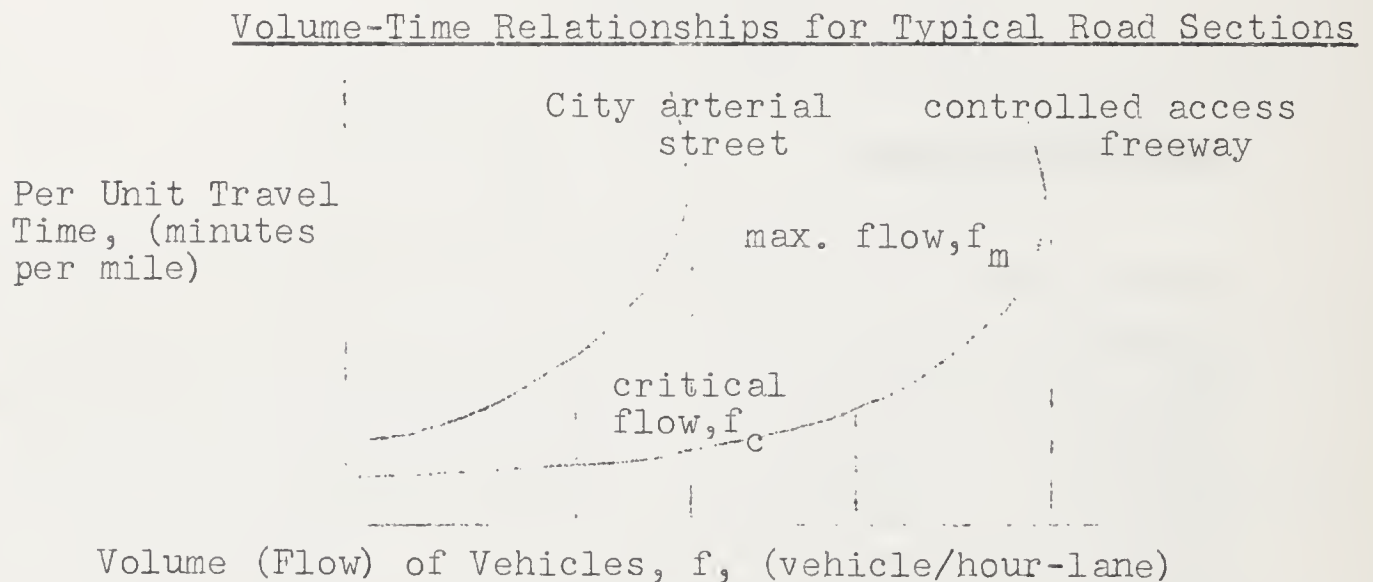


Figure 1

It is shown that the expressway can carry a much greater flow than the city arterial street before congestion causes the per unit travel time to soar. It can also be seen that for each of the road sections shown there is a point, known as the critical flow, f_c , above which the per unit travel time starts to rise rapidly, another point known as the maximum flow, f_m , is the maximum volume that the road can carry. If user demand continues to climb above f_m cars per hour per lane a queue will start forming at some point on the road section and the average travel time per mile experienced by users will increase while the link flow will remain static at f_m cars per hour per lane or in some cases drop off to lower values.

In order to calculate the per unit vehicle travel time on a given link it is necessary to know in mathematical terms the volume-time relationship for that link. As shown above, the shape of this relationship is different for different types of links such as urban arterial roads and controlled access freeways. In the present program, 20 different types of links are defined for this purpose depending on three basic parameters; the speed limit, the number of signalized intersections per mile, and the type of transit vehicles (if any) sharing the road section with automobiles. These twenty link types cover a range from a 30 m.p.h. arterial street with 60 street cars per hour and 10 signalized intersections per mile up to a 60 m.p.h. controlled access freeway.

Data on which these curves are based come from a wide variety of sources. Most prolific of these has been the system of radar detectors mounted at the approaches to several intersections in Toronto as part of the Computer Automated Traffic Control project. Input from these detectors is analyzed every two seconds by the computer in such a way that delay at each intersection approach can be calculated as a function of approach volume. Results from one such location are shown in Plate 6. As shown there the observations have been correlated by three straight line segments.

A representative volume-time relationship has been derived for each link type, based partly on empirical data and partly on theoretical considerations. These twenty relationships so derived are called "capacity functions" and are used in Block 6 to calculate vehicle link travel times as a function of vehicle flows, see Plates 7 and 8. Capacity functions are illustrated in Figure 2.

Capacity Function for Two Typical Types of Road Section

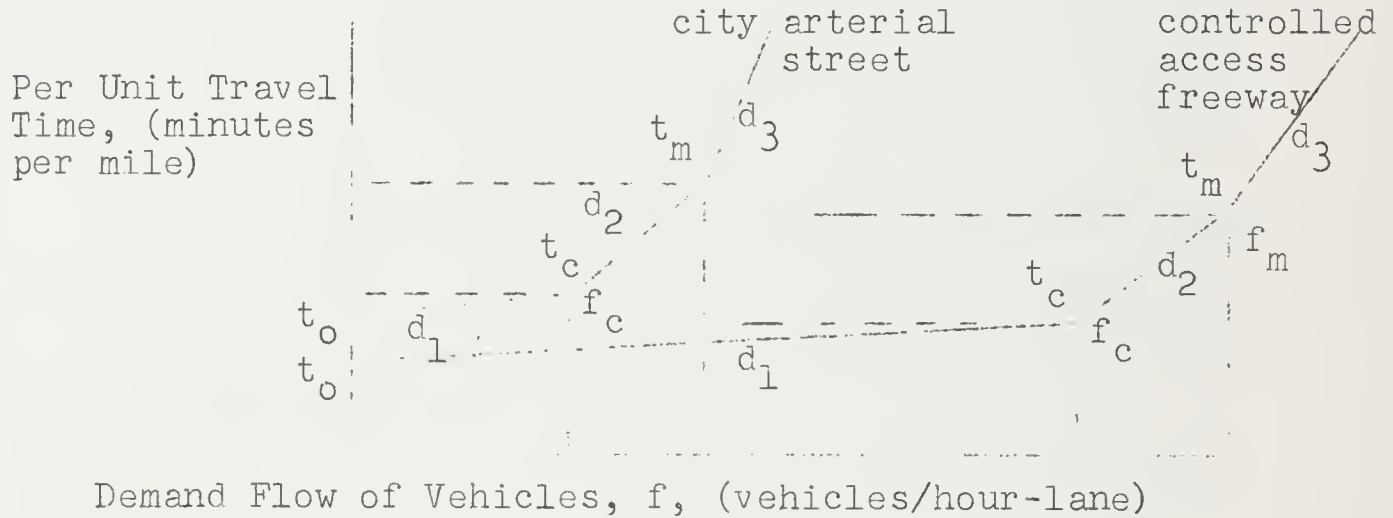


Figure 2

Each capacity function is a simple approximation to the corresponding observed volume-time relationship (shown in Figure 1) for flows less than f_m cars per hour per lane. However, above f_m the capacity function differs from the observed volume-time relationship in that the curve does not double back to the left, but continues to slope off to the right. This is because the independent variable in the capacity function (the variable plotted on the horizontal axis) is the demand flow rather than the actual flow. The actual flow cannot, of course, rise above the maximum flow capacity of a given road section; however, the demand flow can rise above the maximum flow capacity, giving rise to higher average per unit travel times as users wait in queues for their chance to travel along the section. The slope of the capacity function for demand flows greater than f_m cars per hour per lane can be calculated by means of simple queueing theory. As shown in Figure 2, there is a "zero-volume travel time," t_o , which is the average per unit travel time experienced by

a vehicle when there are no other vehicles using the road. Similarly, there is a "critical travel time," (t_c) which is the average per unit travel time experienced when the flow on the road is f_c , the critical flow; and a "maximum flow travel time," (t_m) corresponding to a flow on the road of f_m , the maximum flow. The slope of the capacity function for flows between 0 and f_c (known as the "free-flow" region) is d_1 ; the slope of the capacity function for flows between f_c and f_m (known as the "turbulent" region) is d_2 ; and the slope of the capacity function for demand flows greater than f_m (known as the "overloaded" region) is d_3 . Each of the 20 types of links has a unique set of the seven parameters t_c , f_c , t_m , f_m , d_1 , d_2 and d_3 , which describe fully its capacity function. (See Table on next page)

Mathematically, the general equations describing the capacity functions are as follows:

$$\text{For } 0 \leq f(V) < f_c : t(V) = t_c + d_1(f(V) - f_c) \text{ min/mile (1)}$$

$$\text{For } f_c \leq f(V) < f_m : t(V) = t_c + d_2(f(V) - f_c) \text{ min/mile (2)}$$

$$\text{For } f_m \leq f(V) : t(V) = t_m + d_3(f(V) - f_m) \text{ min/mile (3)}$$

Where:

$f(V)$ is the vehicle demand flow in vehicles per hour per lane
and

$t(V)$ is the average per unit vehicle travel time in minutes
per mile.

It can be seen that if the seven parameters t_c , f_c , t_m , f_m , d_1 , d_2 and d_3 are known for a given road section, and the demand vehicle flow, $f(V)$ (cars per hour per lane) is

TABLE III
CAPACITY TABLE

Type	Speed Limit	Signal intersec. per mile	d ₁	d ₂	d ₃	t _o	t _c	t _m	f _c	f _m
Cars	30	10	0 0 1 3	0 1 8 8	0 5 6 3	4 4	4 9	7 4	4 0 0	5 3 3
		5	0 0 1 1	0 1 6 7	0 5 0 0	3 4	3 9	6 4	4 5 0	6 0 0
		3	0 0 1 0	0 1 5 0	0 4 5 0	3 0	3 5	6 0	5 0 0	6 6 7
		1	0 0 0 8	0 1 2 5	0 3 7 5	2 3	2 8	5 3	6 0 0	8 0 0
Buses	30	10	0 0 1 3	0 1 8 8	0 5 6 3	4 4	4 9	7 4	4 0 0	5 3 3
		5	0 0 1 1	0 1 6 7	0 5 0 0	3 4	3 9	6 4	4 5 0	6 0 0
		3	0 0 1 0	0 1 5 0	0 4 5 0	3 0	3 5	6 0	5 0 0	6 6 7
		1	0 0 0 8	0 1 2 5	0 3 7 5	2 3	2 8	5 3	6 0 0	8 0 0
Street cars	30	10	0 0 1 6	0 2 4 2	0 7 2 6	4 4	4 9	7 4	3 1 0	4 1 3
		5	0 0 1 4	0 2 0 8	0 6 2 5	3 4	3 9	6 4	3 6 0	4 8 0
		3	0 0 1 2	0 1 8 3	0 5 4 8	3 0	3 5	6 0	4 1 0	5 4 7
		1	0 0 1 0	0 1 4 7	0 4 4 2	2 3	2 8	5 3	5 1 0	6 8 0
Cars	40	2	0 0 0 7	0 1 0 0	0 3 0 0	1 9	2 4	4 9	7 5 0	1 0 0 0
		1	0 0 0 6	0 0 8 3	0 2 5 0	1 7	2 2	4 7	9 0 0	1 2 0 0
	50	1	0 0 0 5	0 0 6 8	0 2 0 5	1 5	2 0	4 5	1 1 0 0	1 4 6 7
		0	0 0 0 4	0 0 5 8	0 1 7 3	1 2	1 7	4 2	1 3 0 0	1 7 3 3
Cars	60	0	0 0 0 4	0 0 5 4	0 1 6 1	1 0	1 5	4 0	1 4 0 0	1 8 6 7

also known, then the average per unit vehicle travel time, $t(V)$ (minutes per mile) can be calculated using equation (1), equation (2), or equation (3), depending on whether the given value of 'f' puts the link into the free flow region, the turbulent region or the overloaded region.

Equivalent Vehicle Flow

The demand flow used in equations (1), (2) and (3) does not have to be simply the automobile flow in cars per hour per lane. For links on which transit vehicles and trucks also travel it is possible to calculate an "equivalent vehicle flow," f_e (cars per hour per lane) which takes into account the effects on traffic flow of these other types of vehicle. To obtain the relationship between transit vehicle flow and car flow, conditions at the point of maximum congestion (f_m) were analyzed using observations taken on several major streets in Metropolitan Toronto. The relationship was derived in terms of the number of equivalent cars per transit vehicle (NVPQ) and expressed in the following general equation:

$$F(V) = C + (NVPQ) F(Q) \quad (4)$$

where:

- $F(V)$ is the number of cars per hour;
- C is a constant and is equal to the difference between the extrapolated value of car flow on a transit route with no transit flowing and the theoretical value of a street with cars only at maximum congestion.
- $NVPQ$ is the ratio of cars per transit vehicle and is equal to the inverse of the slope of the graph. (Plate 9).
- $F(Q)$ is the number of transit vehicles per hour.

The analysis yielded the following results for

$$\text{Buses} \quad F(V) = 0 + 4.5 F(Q) \quad (5)$$

$$\text{Streetcars} \quad F(V) = 150 + 3.5 F(Q) \quad (6)$$

It will be noted that C is zero for bus routes (in all cases the agreement was within 5%). Consequently, the capacity function curves as prepared for streets with cars only were directly applicable to streets with buses.

The constant term in the equation for streetcars is explainable by the fact that streetcar tracks themselves impede vehicular flow as does the loading and unloading of passengers. Therefore, it was necessary to develop separate capacity function curves for streets used by streetcars and cars incorporating this constant (see Plate 8).

In the present program these intermodal relationships are described by two parameters, these are NVPQ, the number of equivalent cars per transit vehicle, and NVPT, the number of equivalent cars per truck.

The equivalent vehicle flow, for a link which is used by all three modes, may then be calculated using the following formulas (note: in this context lower case, f, is used to represent flows in cars per hour per lane, and the upper case, F, to represent cars per hour on all lanes of a given link; similarly, lower case, t, always represents minutes per mile, while upper case, T, represents minutes taken to travel from start to end of a given link):

$$F_e(Q) = (NVPQ) \times F(Q) \quad (7)$$

$$F_e(T) = (NVPT) \times F(T) \quad (8)$$

$$F_e(V) = F(V) + F_e(Q) + F_e(T) \quad (9)$$

where:

- $F_e(Q)$ and $F_e(T)$ are the equivalent flows (in terms of equivalent automobiles) of transit vehicles and trucks respectively;
- $F(V)$ and $F(T)$ are the link loads of automobiles and trucks respectively as produced by Block 5;
- $F(Q)$ is the transit flow as given by the transit schedule and listed in a table called the "link table".
- $F_e(V)$ is the equivalent vehicle flow taking into account the effects of transit vehicles and trucks; and
- $NVPQ$ and $NVPT$ are the intermodal parameters described above.

The equivalent vehicle flow per lane is then calculated from the formula

$$f_e(V) = \frac{F_e(V)}{(NULA)} \quad (10)$$

where: $NULA$ is the number of lanes on the link in question.

When the average per unit vehicle travel times have been calculated the average vehicle travel times, $T(V)$, for a given link is calculated by means of the following formula:

$$T(V) = t(V) \times L \quad (11)$$

where: L is the link length in miles.

Effects of Capacity Restraints Summary

The effects of capacity restraints on travel time make themselves felt at four points in the prediction model:

1. In constructing routes. Route generations are carried out under differing conditions of congestion in order to provide several reasonable routes from every Origin to every Destination.

2. In choice of destinations. Trip distributions are carried out under prevailing traffic patterns in order to simulate the effect of congestion on a traveller's choice of destination.

3. In choice of route. Confronted with several possible routes from an Origin to a Destination, travellers are allowed to choose among them so that more choose the route providing the shortest travel time in preference to other available routes.

4. In choice of travel mode. The ratio of travel time by car and by transit is the most important factor affecting modal split.

Many of the relationships can be improved given more accurate source information. Nevertheless, the prediction model in its present stage is capable of producing meaningful results as shown by the test run of the 1956 traffic pattern in Metropolitan Toronto.

APPENDIX III

HOME INTERVIEW SURVEY 1956

Description of Trip Purposes

A brief discussion of each "purpose" is given below:

"Work" applies to trips made to the location of a person's place of employment, such as a factory, a shop, a store, or an office; and, also, to locations that must be visited in performing a normal day's work. The major occupation of a person is classed as "work" even though it be in the nature of a business. Trips made by a doctor in making his calls, and by a salesman calling on prospective customers are classed as trips to work. The purpose "work" would also apply to electricians, carpenters, plumbers, and others who are employed on construction projects and have no regular place of employment.

"Business" refers to trips made to complete transactions not considered part of a person's regular employment. Trips to the bank to transact business, to the post office to mail a letter or package, and to an office to pay a bill, fall in the category of "business". For example, a trip made by a real estate man going to call on a prospect is a trip to work, while a trip to a bank to conduct some business, not a part of his regular occupation is classed as "business".

"Medical and Dental" refers to trips made for consultation about health with doctors, dentists, etc., and does not refer to trips made by doctors or nurses to see patients, which is classed as "work".

"School" refers to students who are actually attending school. This includes public and private schools, universities, colleges, night schools, etc. Teachers and employees at such institutions would be reported as going to "work".

"Social, Recreation" includes cultural trips made to church, civic meetings, lectures, and concerts, as well as trips to attend parties or to visit friends. This item also includes trips made for golfing, fishing, movies, bowling, pleasure riding, etc.

"Change travel mode" applies to trips made to locations where a change in the mode of transportation is made. It is applicable as a trip purpose to that portion of the travel which is necessary to reach the location where the change occurs. For example, a person going to work drives an automobile, and then rides the bus to a point within walking distance of the place of employment. Two trips are involved. The first, from "home" to "change travel mode" as an automobile driver, and the second, from "change travel mode" to "work" as a bus rider. Other combination modes of travel should be recorded in a similar manner. Transfers made from one street-car or bus line to another do not constitute a change in mode of transportation.

"Shopping" should be circled whenever a trip is made to do some shopping, regardless of the size of the purchase. Trips made to a store for the purpose of "just looking" are classed as shopping even though no purchase is made. Trips made for repairs to automobiles, radios, or other items, and for personal services such as haircuts, beauty treatments, cleaning and pressing clothes, etc., also should be recorded as shopping.

"Serve Passenger" should be recorded as the purpose of trips or stops made in an automobile to pick up or deliver someone at a specific location. This purpose, for the most part, is used in connection with auto driver trips; however, it is also applicable to auto passenger trips in certain other instances. A wife drives from home to pick up her husband at work and they both start home, but with the husband driving instead of the wife. En route home the husband stops at a grocery store to let his wife do some shopping. Five trips (three for the wife and two for the husband) are involved.

"Home" refers specifically to the address of the household being interviewed. Trips should never be recorded as proceeding from "home" to "home". This would indicate a round trip, which is not permissible in this study.

Figure 1 is a line graph showing the relationship between the ratio of transit to automobile travel time (X-axis) and the percentage of all work trips made by transit (Y-axis). The X-axis ranges from 0.0 to 8.0, and the Y-axis ranges from 0 to 100. The graph includes a legend for the number of work trips (BTW) and a curve labeled 'x' representing the overall trend.

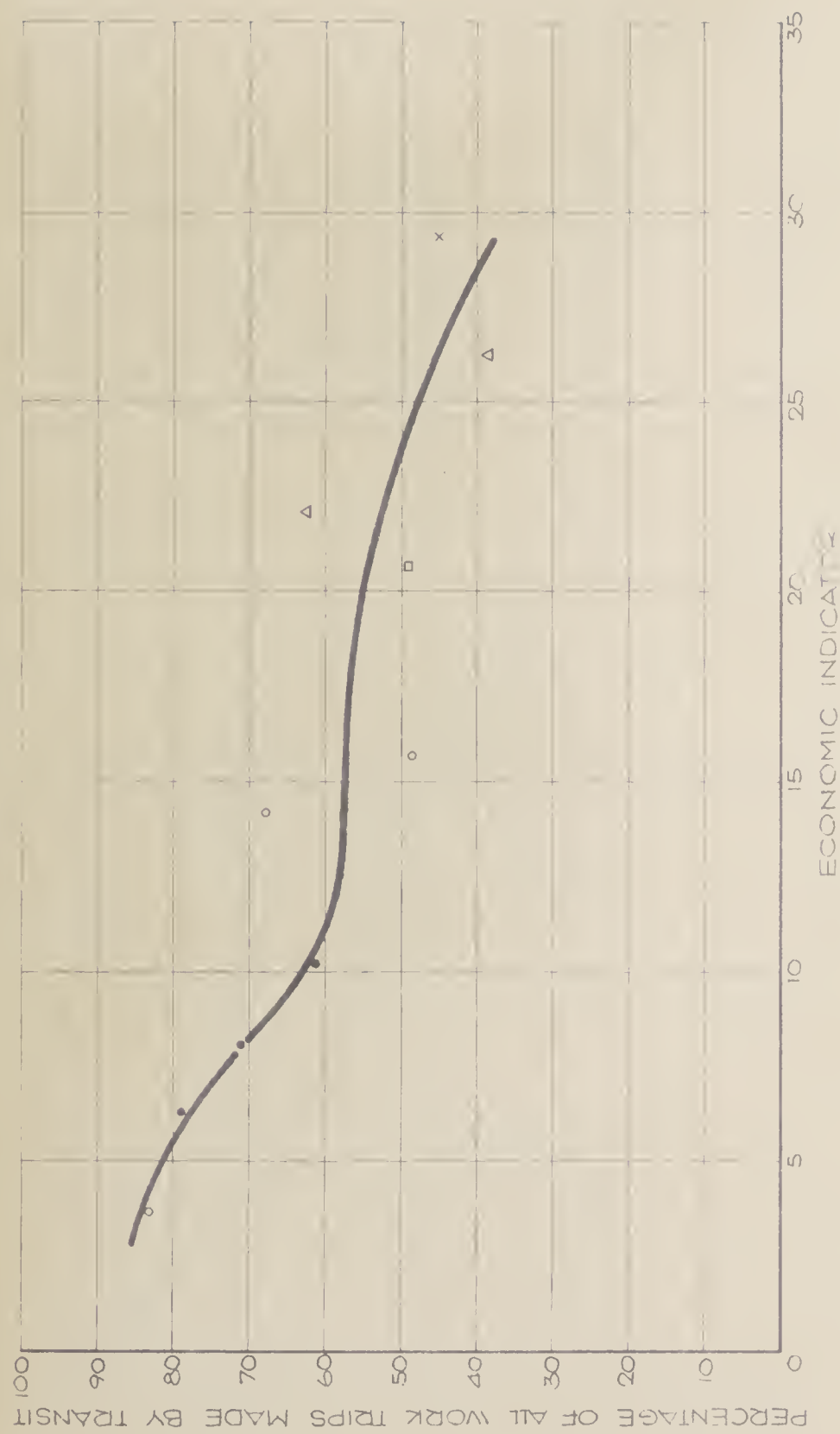
Legend:

- NUMBER OF WORK TRIPS 0-200
- △ NUMBER OF WORK TRIPS 200-500
- NUMBER OF WORK TRIPS 500-1000
- NUMBER OF WORK TRIPS OVER 50,000

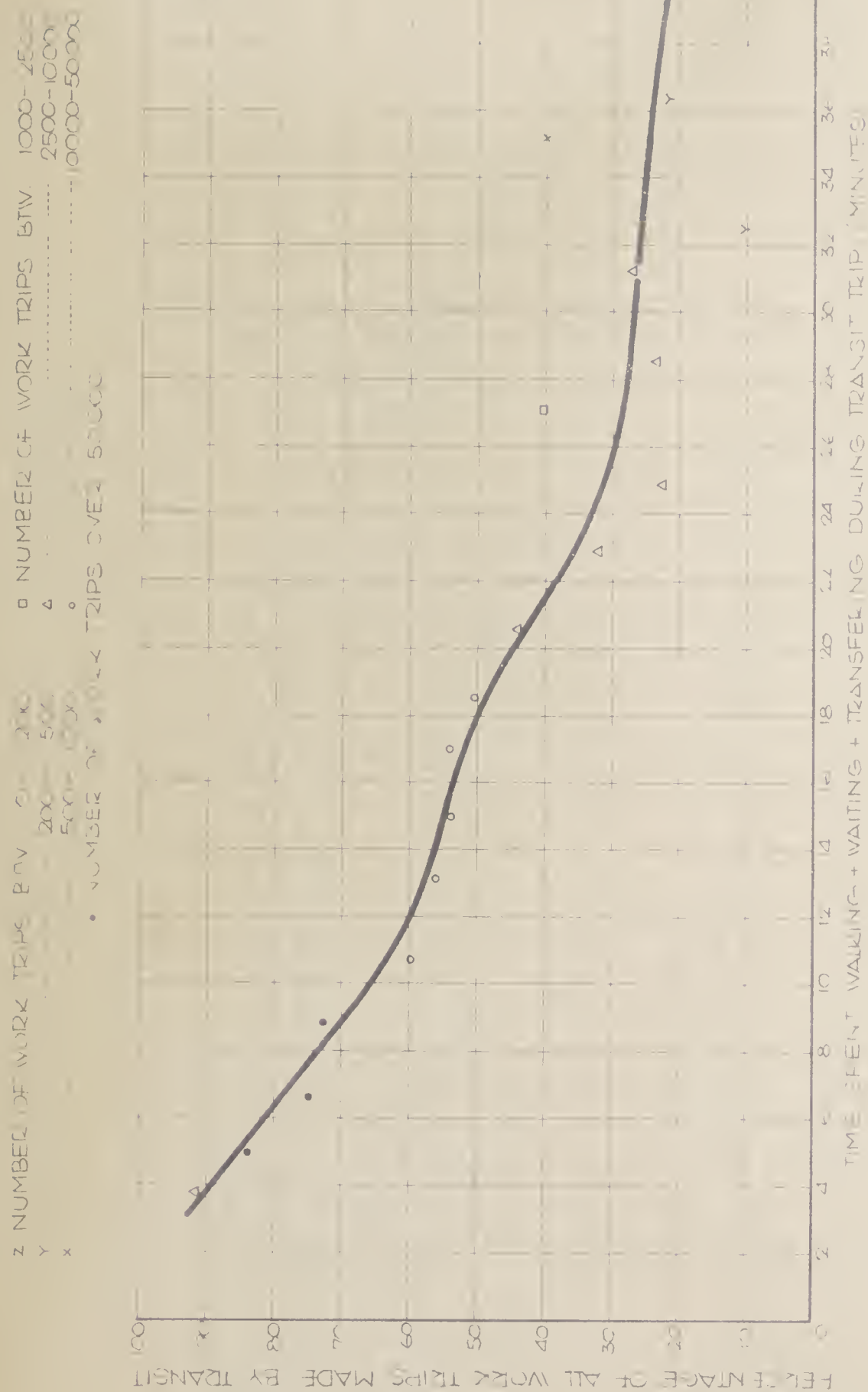
The curve 'x' shows that as the ratio of transit to automobile travel time increases, the percentage of all work trips made by transit also increases, starting from approximately 5% at a ratio of 0.0 and reaching approximately 25% at a ratio of 8.0.

Ratio of Transit to Automobile Travel Time (X)	Percentage of All Work Trips Made by Transit (Y)	Number of Work Trips (BTW)
0.0	5	0-200 (△)
1.0	10	0-200 (△)
1.5	15	500-1000 (○)
2.0	20	0-200 (•)
2.5	25	0-200 (•)
3.0	30	0-200 (•)
4.0	40	0-200 (•)
5.0	50	0-200 (•)
6.0	60	0-200 (•)
7.0	70	0-200 (•)
8.0	80	0-200 (•)

z NUMBER OF WORK TRIPS BTW. 0- 200 □ NUMBER OF WORK TRIPS BTW. 1000 - 2500
y 200 - 500 Δ 2500 - 10000
x 500 - 1000 ○ 10000 - 50000
• NUMBER OF WORK TRIPS OVER 50000



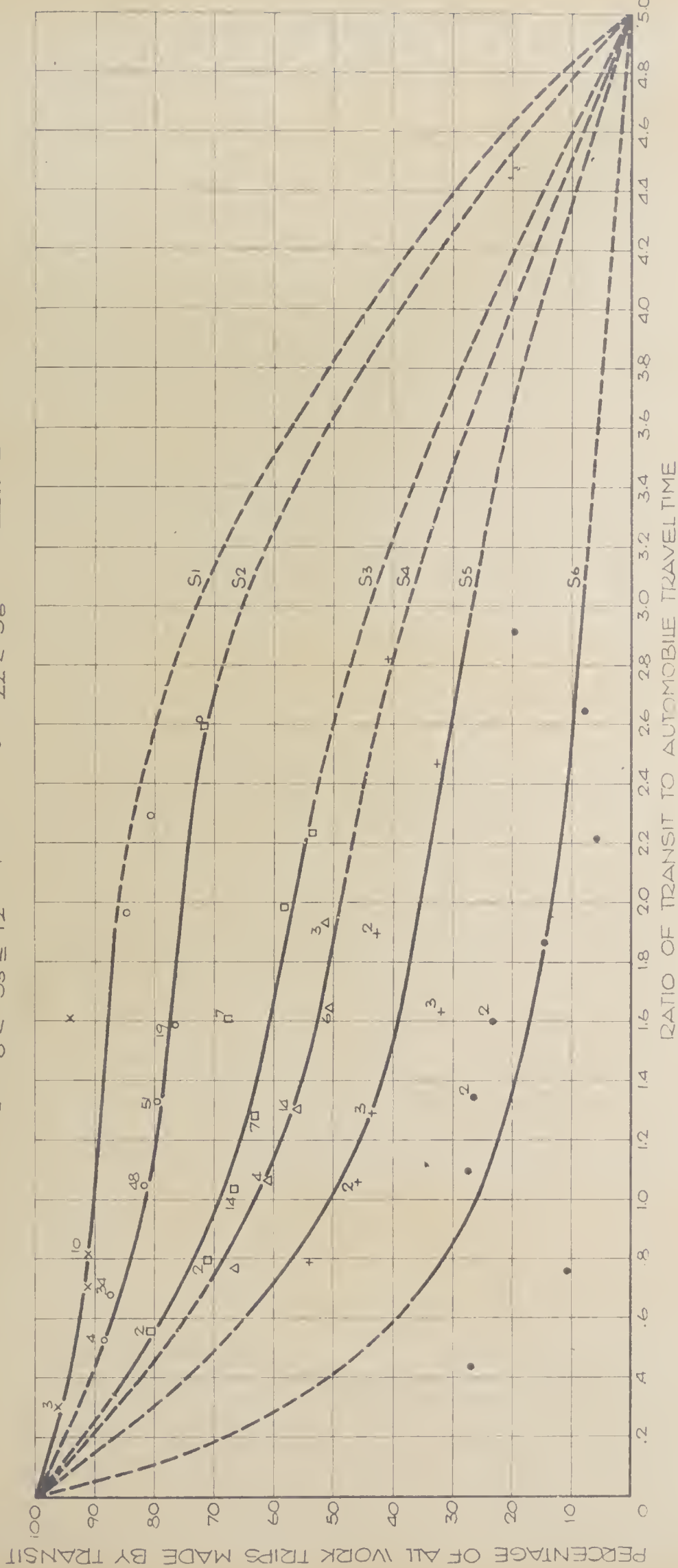
TRANSIT SHARE OF WORK TRIPS
RELATED TO THE ECONOMIC INDICATOR



TRANSIT SHARE OF WORK TRIPS RELATED TO TOTAL WALKING AND WAITING TIMES

NOTE: LEVEL OF O-D TRANSIT SERVICE

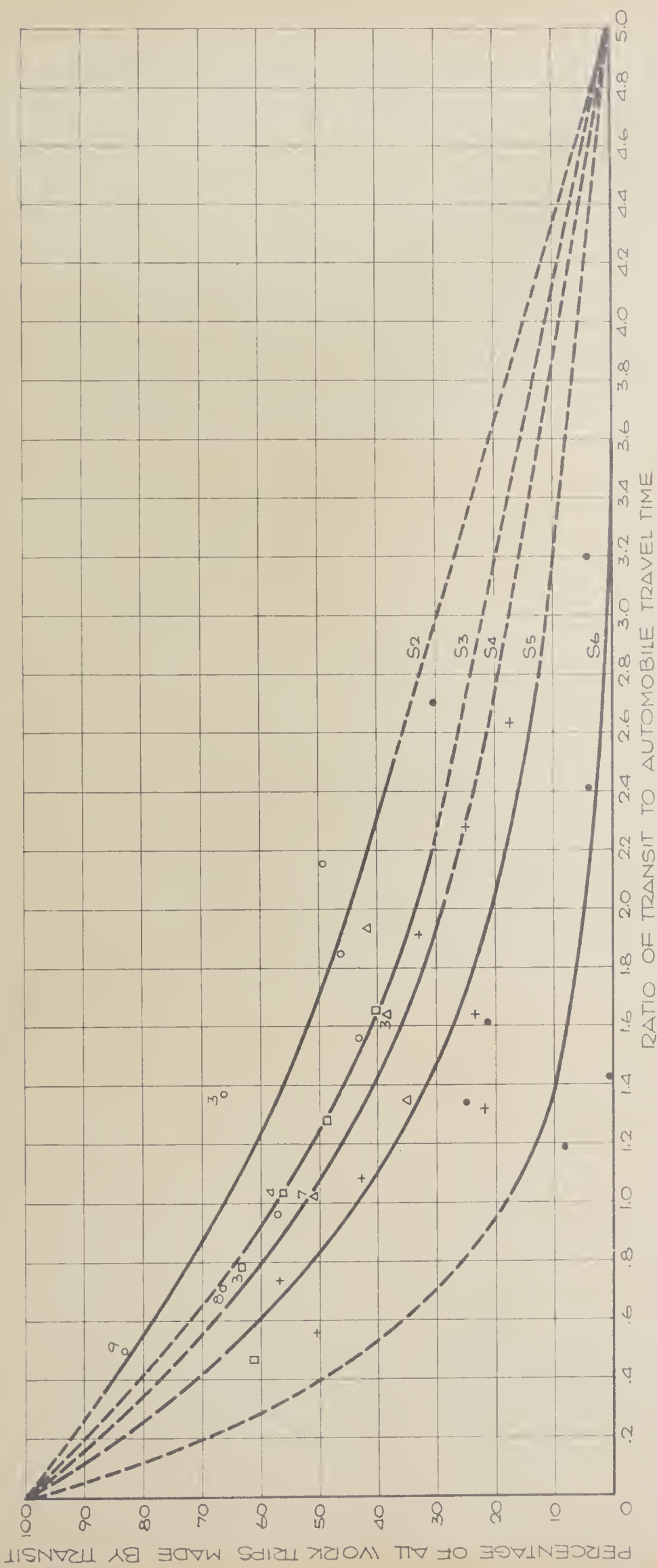
- x $S_1 \leq 4$ MINUTES
- o $4 < S_2 \leq 8$ — " —
- $8 < S_3 \leq 12$ — " —
- Δ $12 < S_4 \leq 18$ MINUTES
- + $18 < S_5 \leq 22$ — " —
- $22 < S_6$ — " —



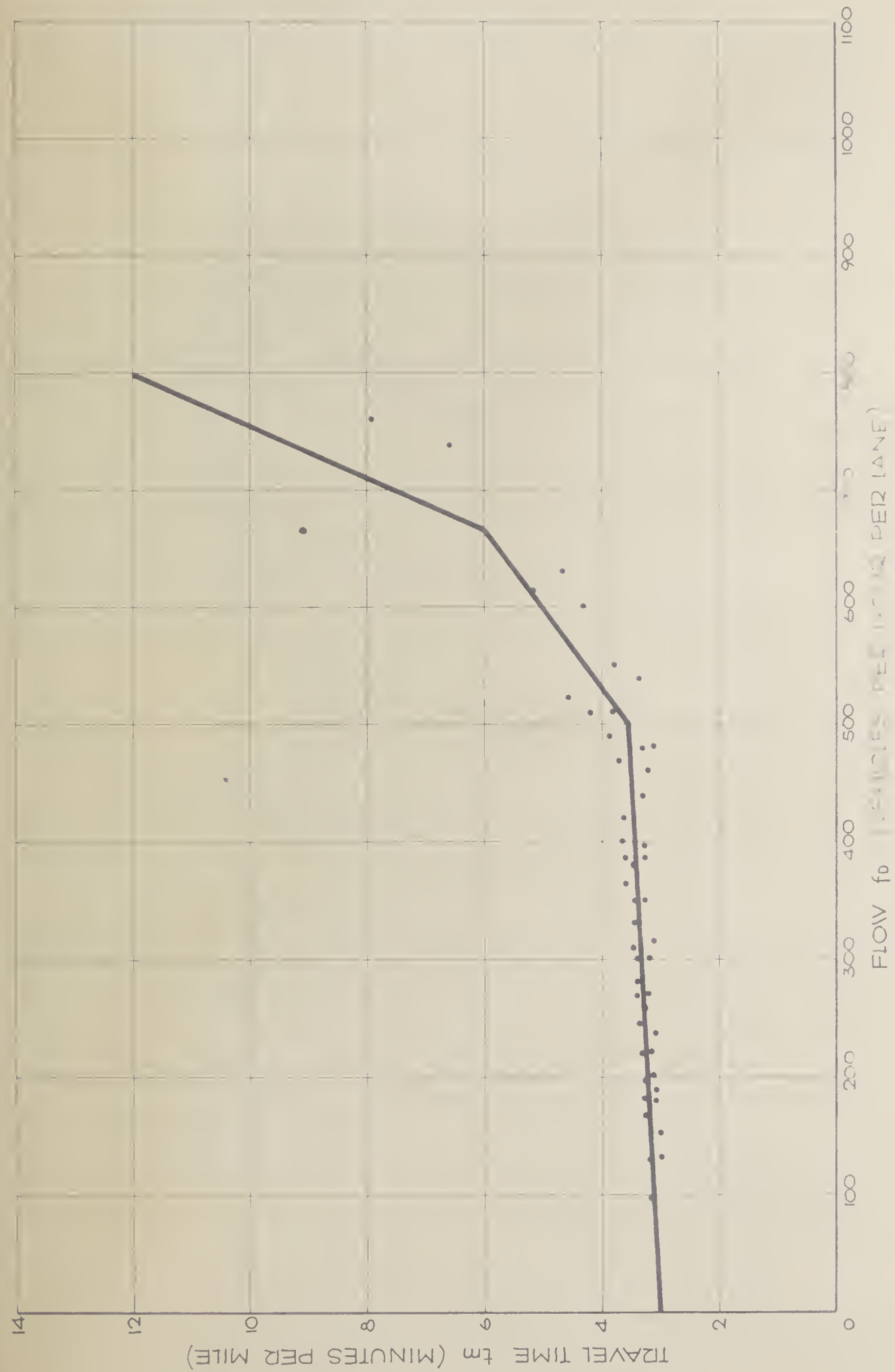
TRANSIT SHARE OF WORK TRIPS
RELATED TO RATIO OF TRANSIT TO AUTOMOBILE TRAVEL TIME

NOTE: LEVEL OF O-D TRANSIT SERVICE

- x $S_1 \leq 4$ MINUTES
- o $4 < S_2 \leq 8$ " " " "
- $8 < S_3 \leq 12$ " " " "
- Δ $12 < S_4 \leq 18$ MINUTES
- + $18 < S_5 \leq 22$ " " " "
- $22 < S_6$ " " " "



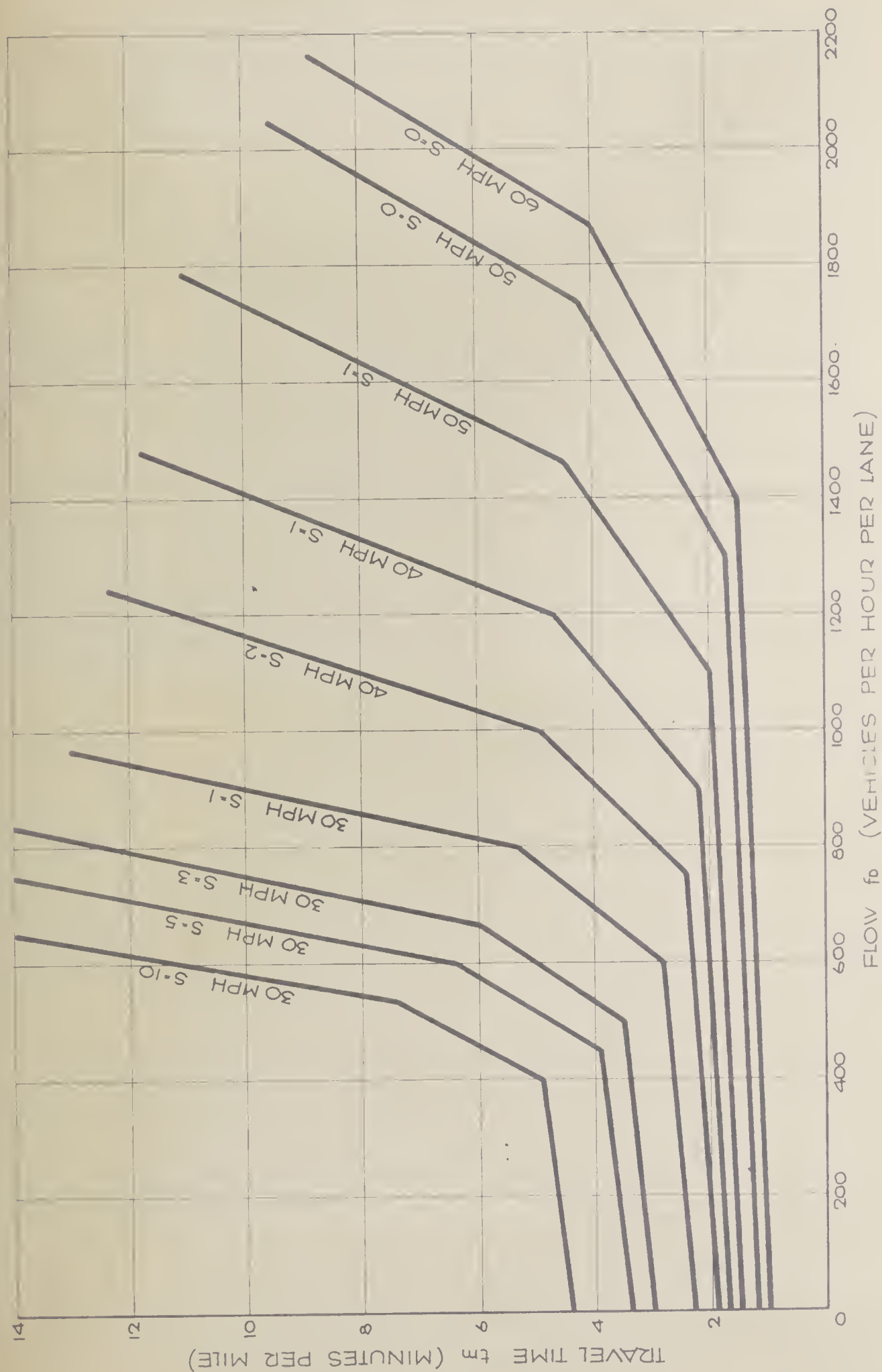
TRANSIT SHARE OF WORK TRIPS RELATED TO RATIO OF TRANSIT TO AUTOMOBILE TRAVEL TIME



CAPACITY FUNCTION

FOR ROADS WITH CARS ONLY

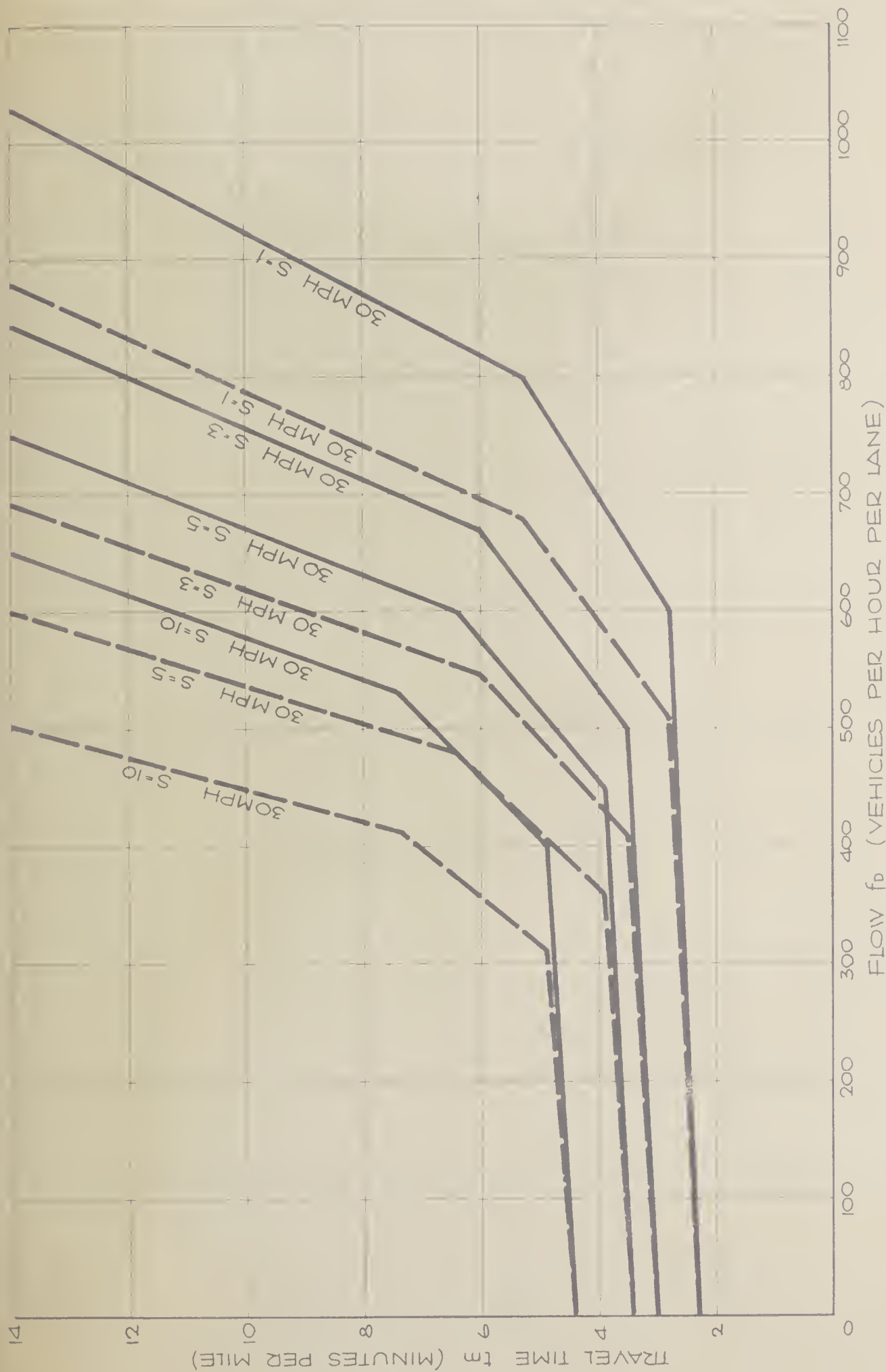
30 M.P.H. $S=3$



CAPACITY FUNCTION CURVES

FOR ROADS WITH CARS ONLY

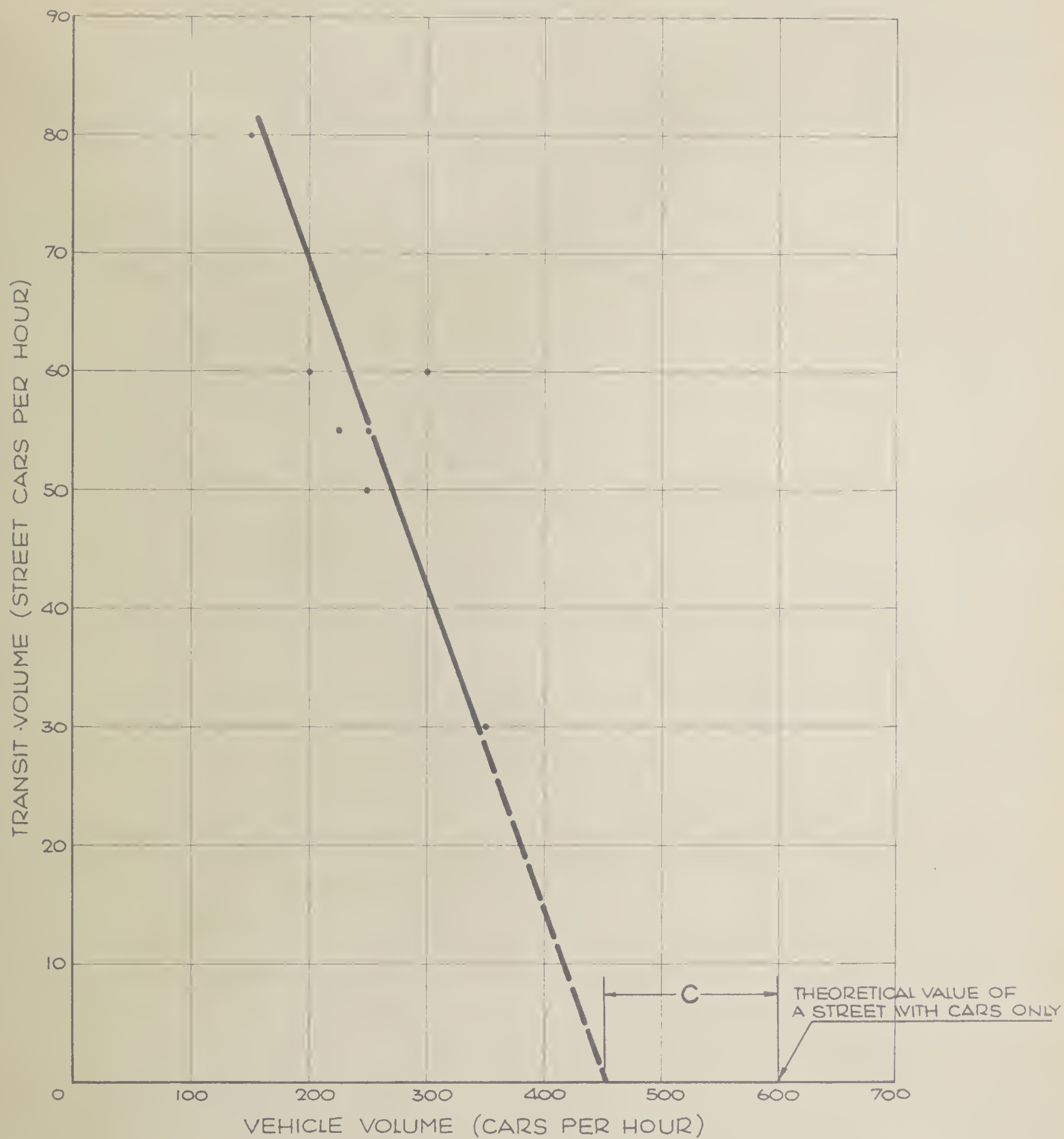
TRAFFIC PREDICTION MODEL TORONTO 1956



CAPACITY FUNCTION CURVES

FOR ROADS WITH : BUSES — STREET CARS —

TRAFFIC PREDICTION MODEL TORONTO 1956



TRANSIT VOLUME (STREET CARS)

VS.

VEHICLE VOLUME (CARS)

AT MAXIMUM CONGESTION ON ROADS WITH $S=5$ AND S.L.=30 M.P.H.

